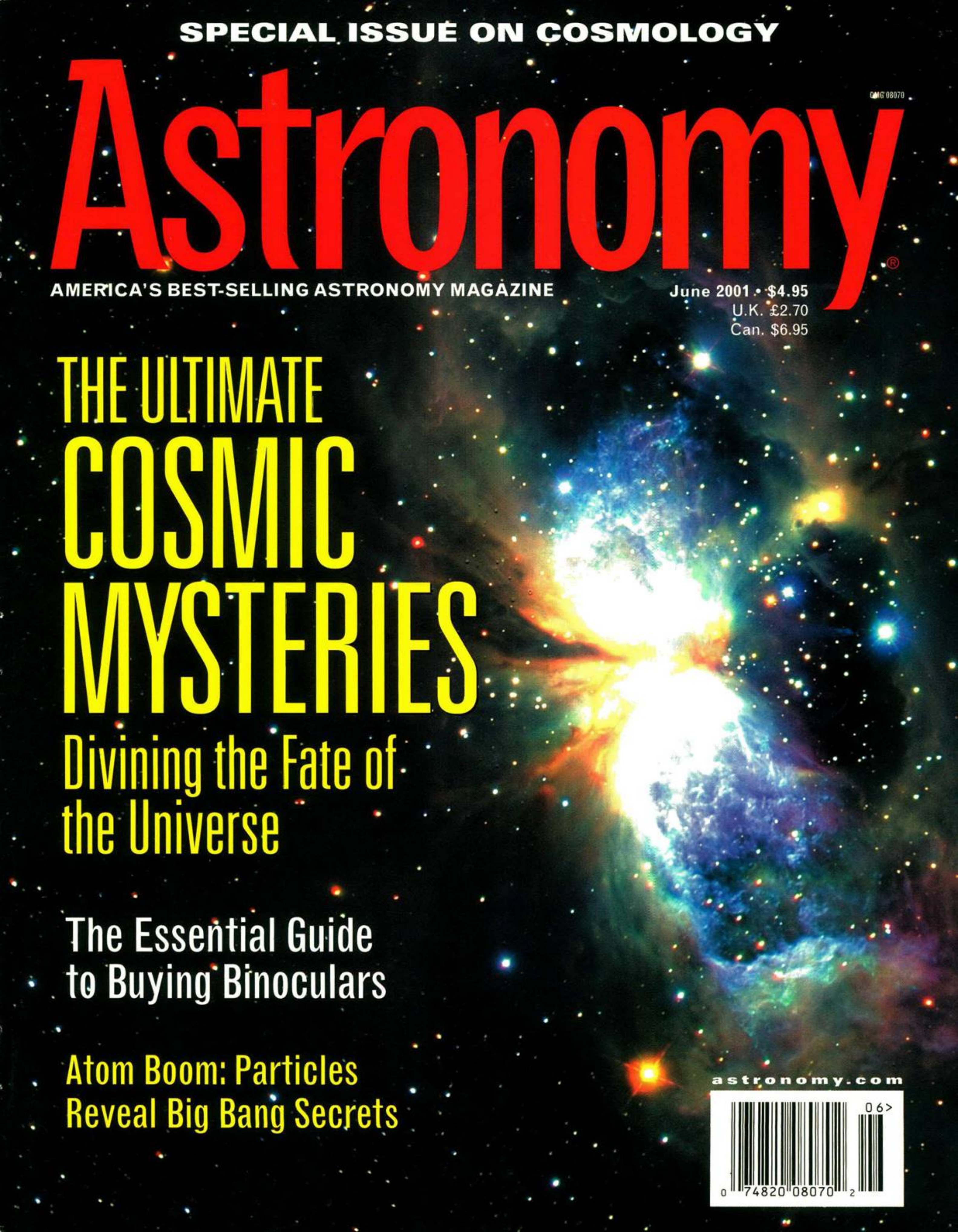

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Meade 8" LX10 Schmidt-Cassegrain Telescope.
Complete as shown with equatorial wedge and hand controller and, for a limited time, with *free* LX10 Field Tripod:

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For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *Standard-equipment includes:*

Super-Multi-Coated Optical System: The *exact same* multi-coated 8" Schmidt-Cassegrain optical tube assembly as the more expensive Meade 8" LX200.

Series 4000 Super Plössl 26mm eyepiece: An $80 eyepiece, the SP26mm complements the exquisite imaging of Meade 8" Schmidt-Cassegrain optics.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power visual applications of the telescope, or for photographic or CCD imaging.

Cordless, DC-Powered Electronic Motor Drive: With electronically-regulated DC servo motor for automatic *sidereal-rate* tracking; powered for 50 hours by four AA-size batteries that fit conveniently into the telescope's control panel.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope in R.A. at 2x speed during long-exposure astrophotography. With the optional electric Declination motor *(see below)* added to the telescope, the hand controller is functional at 2x speeds on both telescope axes.

LX10 Field Tripod: The chromed steel LX10 Field Tripod provides an extremely rigid platform for visual and photographic observations with the telescope. Regularly $195, this tripod is included **free of charge** for a limited time with your purchase of the 8" LX10 telescope. *This free offer is valid from January 15, 2001 until further notice at participating dealers in the U.S.A.*

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4- pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); SP26mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; LX10 Field Tripod (included only for a limited time, as noted above); complete operating instructions.
$995. (+ $65 packing & shipping in the 48 states)

Electric Declination Motor System for LX10	**95.**
#2014 Magellan I Telescope Computer System for LX10 with 12,218-object database	**375.**

Prices shown are suggested U.S. mail-order prices. © 2001

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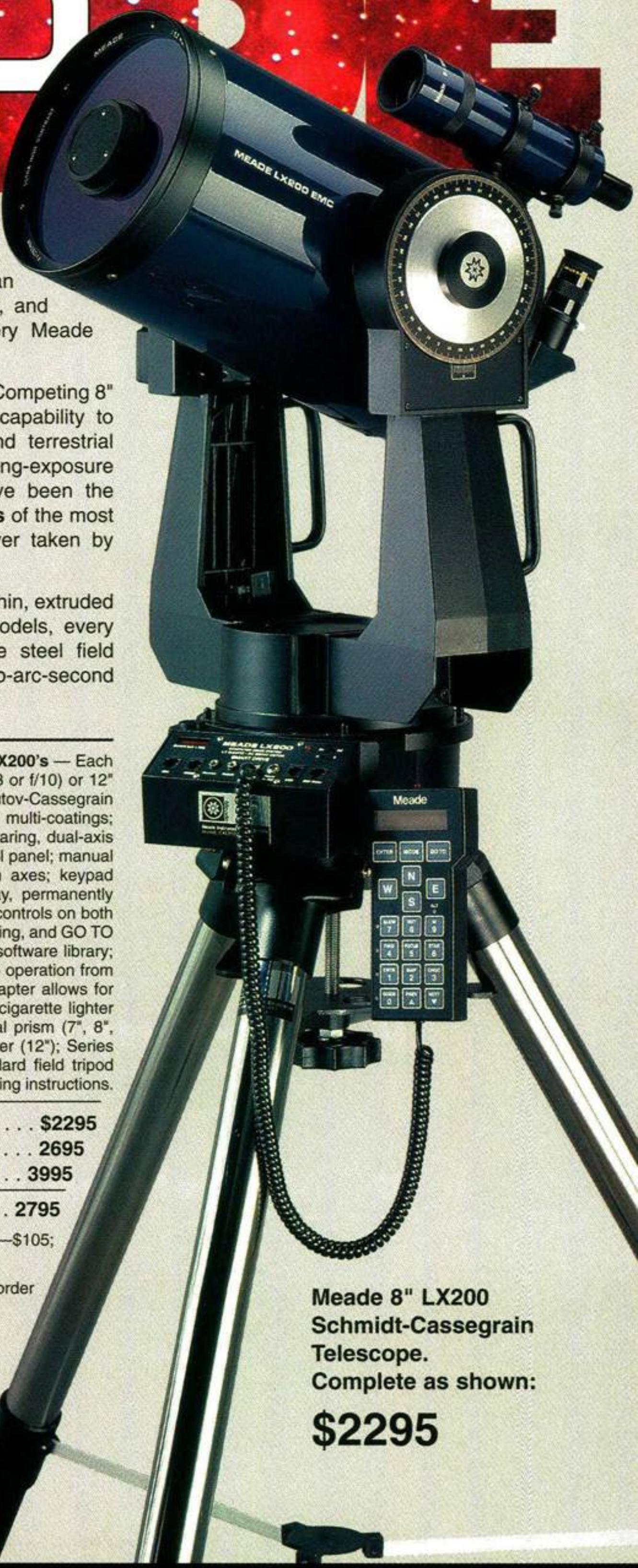
MEADE LX200



The largest-selling serious telescopes in the world are now available at the most affordable prices *ever!*

With their large object databases, fast slewing speeds, and uncanny pointing precision, Meade LX200's are recommended for those amateurs who intend an extensive program of CCD imaging, astrophotography, or deep-space observing. Compare a Meade LX200 feature-for-feature with competing single-tine-fork, spur-gear-driven, GO TO Schmidt-Cassegrains:

Superb Optics: With oversize primary mirrors for greater full-field illumination, LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.

Automatic GO TO Capability: Competing 8" Schmidt-Cassegrains claim to place objects "somewhere in the field of view"; Meade LX200's place objects **dead-center** in the field of view, first time, every time, to a pointing precision of **2 arc-minutes or better,** or, with Meade exclusive High Precision Pointing, to a precision of **one arc-minute or better.** *Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any object in the onboard database, to these levels of precision.*

Database of 64,359 Objects, a database *more than three times larger* than competing GO TO telescopes.

Permanently-Programmable Smart Drive™ routinely achieves 5 arc-sec. periodic error, an observatory standard. Other brands of GO TO 8" SCT's decline to state their periodic error and do not offer any programmable error-corrector.

9-Speed Dual-Axis Electronics: Electronics that cover every contingency of telescope positioning — from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, plus 6 other dual-axis drive speeds in between.

Rigid LX200 Dual-Tine Fork Mountings with Dual 5.75" Worm Gears are the choice of advanced observers, CCD imagers, and astrophotographers for their most sensitive applications. Competing spur-gear-driven single-tine forks can not approach the strength, rigidity, and drive-rate precision built into every Meade LX200 mounting.

Full Long-Exposure Capability: Competing 8" GO TO telescopes describe their capability to take short-exposure "planetary and terrestrial photos," without reference to any long-exposure capabilities. Meade LX200's have been the instruments of choice in **thousands** of the most detailed long-exposure images ever taken by amateur astronomers.

Strong Field Tripods: Unlike the thin, extruded aluminum tripods of competing models, every LX200 includes a fully adjustable steel field tripod perfectly suited to the sub-arc-second resolution of the telescope's optics.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2295**
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Prices shown are suggested U.S. mail-order retail prices.

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COVER PHOTO: Subaru Telescope, NAOJ

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From *The Glorious Constellations*, © 1991; Harry N. Abrams, Inc.

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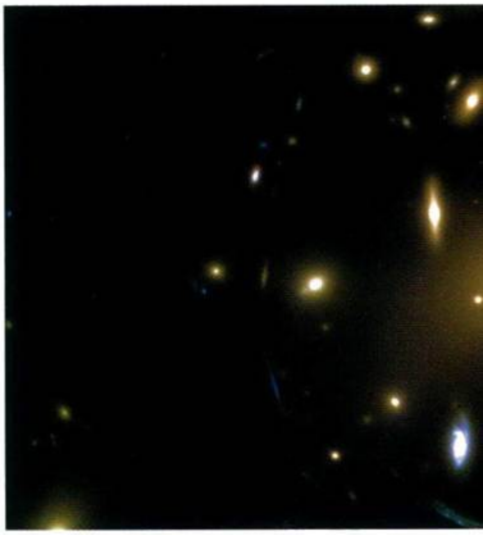
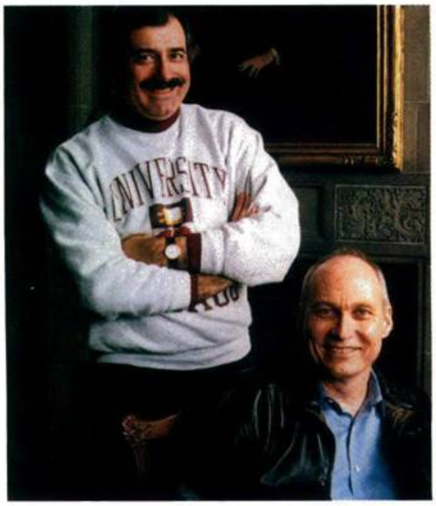
August R. Orlandi





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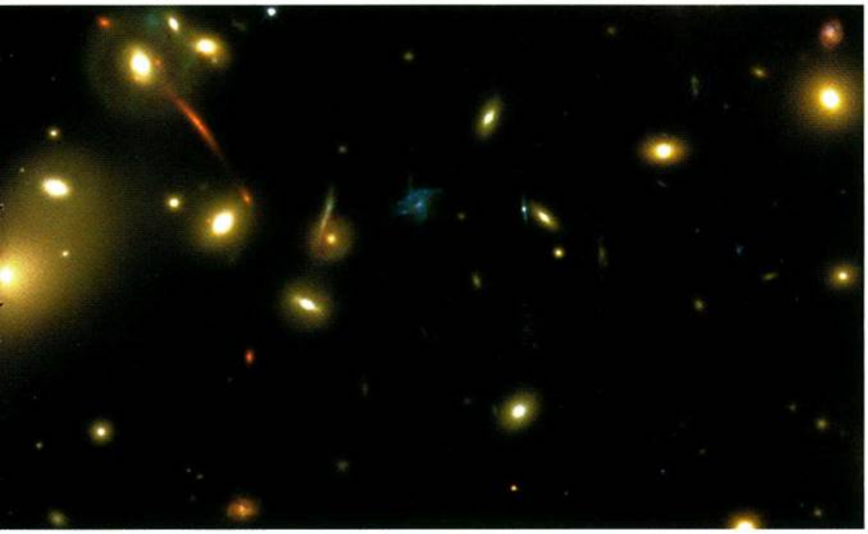

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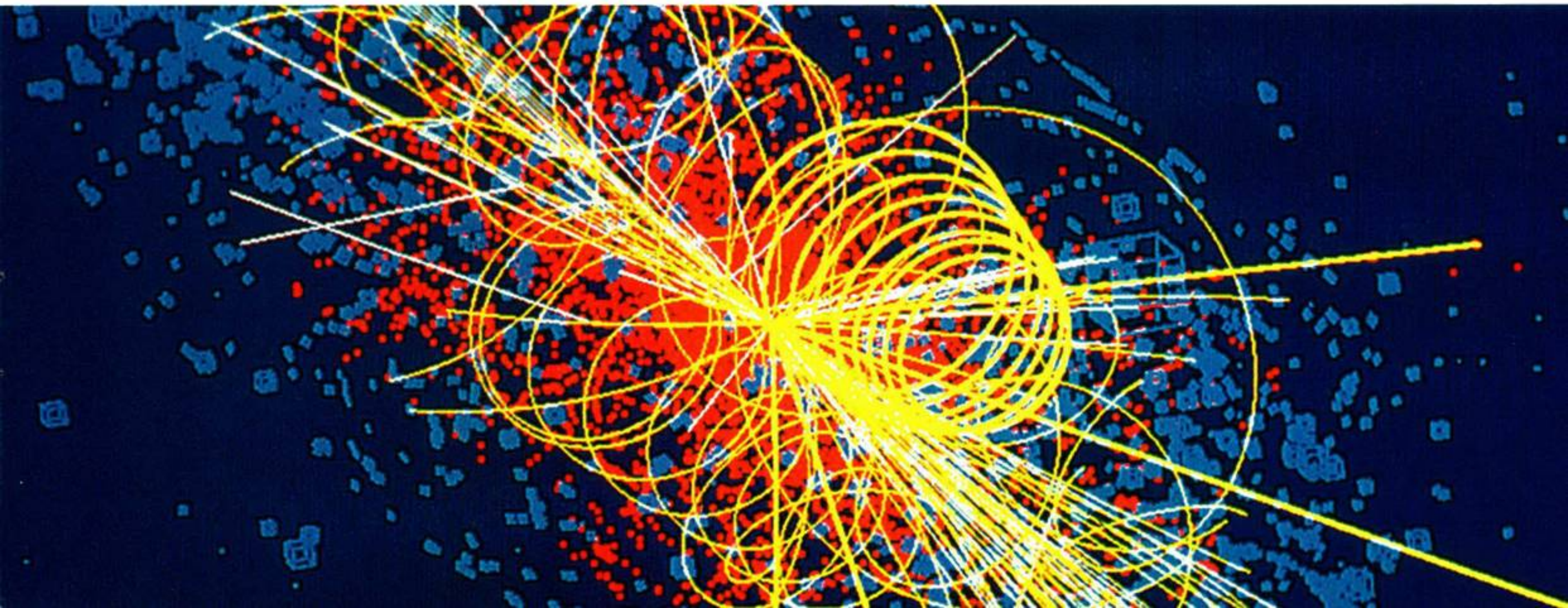


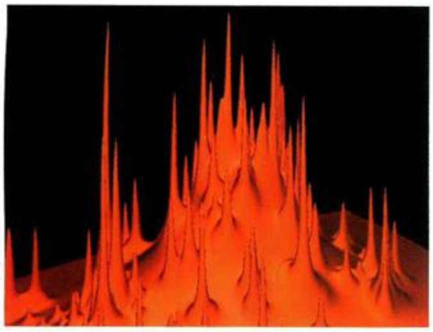
BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Divining the Fate of the Universe

One of our contributing editors, Ray Jayawardhana, mentioned last month that he was happy to live in this ambiguous world despite its many unsettled questions. "If we knew about everything that shapes the universe, I wouldn't have a job," he says. He's an astrophysicist at the University of California, Berkeley.

Astrophysicists probably won't have to look for retraining courses anytime soon. Of the thousands of unsettled astronomical issues, our editors have selected eight big ones that should keep all astronomers employed for years to come.


Anthony Tyson, AT&T Bell Laboratories

Dark matter fills the voids between galaxy "spikes" in the cluster Abell 2218.

To get the whole story on the biggest problems in cosmology, turn to our three-part special report that begins on page 36. In this series of stories, Mark Sincell explains the grandest and most current cosmological problems of the day. Robert Zimmerman expounds on a trend that is bringing astronomers and molecular physicists closer together: They are looking inside atoms to try to understand how the Big Bang came out of nothing. And *Astronomy* senior editor Rex Graham writes about the lives of two scientists who have been on the front lines of cosmological study.

It's hard to believe that 100 years ago humans rarely flew and thought the Milky Way Galaxy was the extent of our universe.

On another sadder note, one of our authors, James Schefter, died in January 2001. He had recently provided us with the tender profile of Soviet cosmonaut Yuri Gagarin that ran in the April 2001 issue. Schefter spent many years covering the space program for *Time* and *Life* magazines and wrote several books, including *The Race: The Uncensored Story of How America Beat Russia to the Moon*, which was published in 1999.

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Precision, heavy-duty equatorial mount with DC-powered drive system for fully automatic tracking.

Shown with optional #2011 Magellan I Computer System.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

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Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System: For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries or from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 1.25" and 2" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 giant focuser.

Magellan I Telescope Computer System: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade Starfinder Equatorial 6", 8", or 10"	**$295.**
#2012: for Meade Starfinder Equatorial 16"	**295.**

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for Starfinder Equatorial 6", 8", 10"	**495.**
#2019: for Starfinder Equatorial 16"	**595.**

Packing & shipping in the 48 states: Magellan I – $15, Magellan II – $20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

Meade Starfinder Equatorial Telescopes

6" f/8	**$499**	**10" f/4.5**	**699**
8" f/6	**599**	**16" f/4.5**	**2695**

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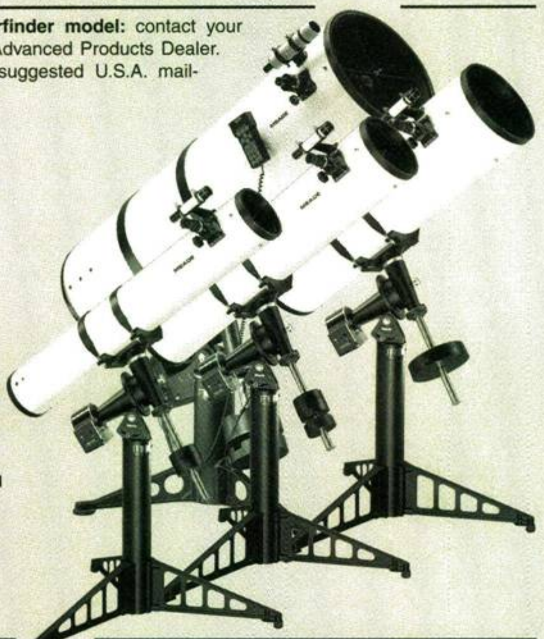
To Order any Starfinder model: contact your authorized Meade Advanced Products Dealer. Prices shown are suggested U.S.A. mail-order retail prices.



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Let Meade high-resolution ETX optics and standard-equipment Autostar controller take you on an automated guided tour of the Solar System, the Galaxy, and beyond.

Fork Mount with Dual-Axis Drive System: Precision worm gear systems permit smooth pushbutton motions of the telescope, as well as sidereal-rate tracking in the altazimuth mode.

Free #882 Field Tripod!

For a limited time you can purchase a Meade ETX-60AT or ETX-70AT Astro Telescope and receive a full-length Meade #882 Standard Field Tripod (regularly $99), **absolutely free.** The #882 Tripod is ideal for either seated or standing observations through the telescope. *This offer is valid from January 15, 2001, until further notice, at participating Meade dealers in the U.S.A.*

Standard-Equipment #494 Autostar™ Controller: Includes most of the same features as the more advanced #497 Autostar available for larger ETX models *(facing page).*

- **Automatic dual-axis GO TO function at 4.5°/sec.** to any of more than 1450 database objects, including the complete Messier and Caldwell deep-space object catalogs, the major planets from Mercury to Neptune, 26 asteroids, 15 periodic comets, and more. Or GO TO *any* object of known R.A. and Dec.
- **9-speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 4.5°/sec., plus sidereal-rate tracking.

High-Resolution Achromatic Objective Lenses *of exclusive Meade design*; each lens yields razor-sharp images of astronomical and terrestrial subjects.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #933 45° Erecting Prism or for photography with the optional #64ST Photo Adapter.

Cordless Operation: The dual-axis drive operates for over 20 hours in the field from six AA-size (user-supplied) batteries which store neatly inside the drive base.

MEADE ETX-60AT • ETX-70AT

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Guided Tour Tonight's Best
MEADE
COMPUTER CONTROL

ETX-70AT: $349, complete with #494 Autostar Controller and #882 Standard Field Tripod

ETX-60AT: $299, complete with #494 Autostar Controller and #882 Standard Field Tripod

SPECIFICATIONS: ETX-60AT and ETX-70AT Astro Telescopes — Each includes achromatic refractor optical tube assembly (D = 60mm, F = 350mm, f/5.8 *or* D = 70mm, F = 350mm, f/5) with multi-layer optical coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles, and locks on both axes; electronic control panel; 9-speed (2x sidereal through 4.5°/sec.) dual-axis motor drive system with #494 Autostar computer controller; sidereal-rate tracking; internal compartment accepting six (user-supplied) AA-size batteries; MA9mm (39X) and MA25mm (14X) multi-coated eyepieces; #882 Standard Field Tripod (included only for a limited time, as noted above); operating instructions. **ETX-60AT — $299** (+$10 packing & shipping in the 48 states); **ETX-70AT — $349** (+$10 P & S).

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#773 Hard Carry Case (60, 70)	59.95	#774 Hard Carry Case (90)	99.95
#933 45° Erecting Prism (60, 70)	49.95	#775 Hard Carry Case (125)	149.95
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#881 Equatorial Table Tripod (125)	59.95		

**see also the Meade accessory ad in this issue.*

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ETX-90EC:
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Meade® 3.5" and 5" ETX® models include the very latest in microprocessor-controlled capability:

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Pushbutton Electronic Hand Controller: Use any of four dual-axis speeds: 8x for image centering at high power; 32x for image centering at lower power; 0.75°/sec for image centering in the viewfinder or for terrestrial tracking; 5°/sec for fast slewing across the sky.

Maksutov-Cassegrain Optical Systems: Manufactured at the Meade Irvine, facility, ETX diffraction-limited optics produce images so high in contrast and resolution that ETX telescopes often outperform other telescopes of larger apertures.

Flip-Mirror System: Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter.

Cordless Operation: The dual-axis drive system operates for more than 40 hours from eight (user-supplied) AA batteries which store neatly inside the drive base.

Special Offer: ETX-90EC now $495!

Now for a limited time you can purchase the Meade ETX-90EC Astro Telescope — the largest-selling modern telescope in the world — at $495, a savings of $100 off the regular price. *This offer is valid from January 15, 2001, until further notice, at participating Meade dealers in the U.S.A.*

Optional #497 Autostar™ Now Only $99 (regularly $149) For a Limited Time! Plug in the optional Meade #497 Autostar computer controller for LX200-type operation, including:

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MODE
GO TO

- **Automatic dual-axis GO TO function at 5°/sec** to any of more than 14,000 database objects, including thousands of deep-space objects; the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; and more.
- Select any of Autostar's database objects, or any object of known R.A. and Dec, press ***GO TO*** and the telescope automatically slews to the object.
- **9-Speed Dual-Axis Operation:** Pushbutton control of the telescope on both axes, simultaneously, at any speed from 2x sidereal to 5°/sec., plus sidereal-rate tracking.

SPECIFICATIONS: ETX 90EC and ETX-125EC Astro Telescopes — Each includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8 *or* D = 127mm, F = 1900mm, f/15) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; fork mount with electric slow-motion controls, setting circles and locks on both axes; electronic control panel; 4-speed (8x, 32x, 0.75°/sec, 5°/sec) dual-axis motor drive system with hand controller; sidereal-rate tracking in equatorial mode with optional table tripod or deluxe field tripod; internal battery compartment accepting eight (user-supplied) AA-size batteries; 8 x 21mm erect-image (ETX-90EC) *or* 8 x 25mm right-angle (ETX-125EC) viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); instructions. **ETX-90EC — $495** (+ $20 packing & shipping in the 48 states); **ETX-125EC — $895** (+ $30 P & S).

AUTHORIZED U.S. AND CANADA MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

6001 Oak Canyon, Irvine, CA 92618. (949) 451-1450. FAX: (949) 451-1460. www.meade.com

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RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

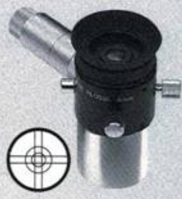
6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B

#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

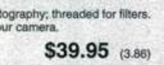
As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (3.86)

Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

NEW!
MEADE
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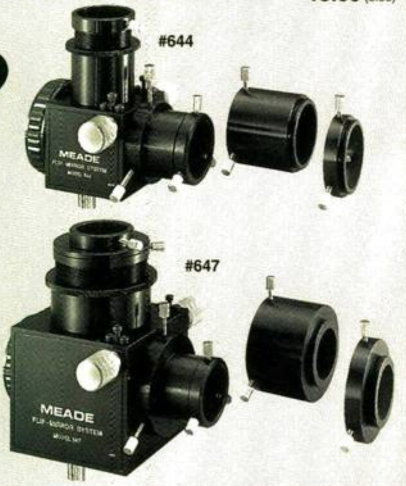
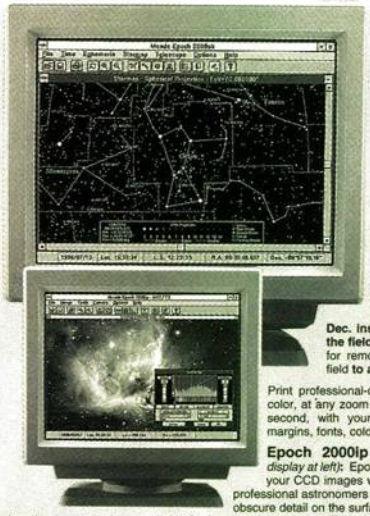




Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left):* Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95	**$149**
EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM	**179**
LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk	**25**
EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95	**$199**

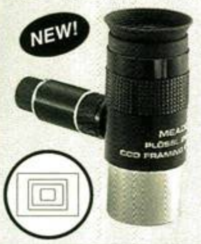
f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular



Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

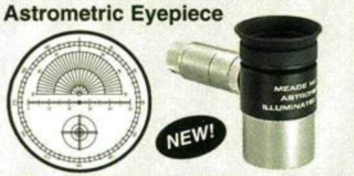
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

NEW!

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

ETX® Hard Carrying Cases

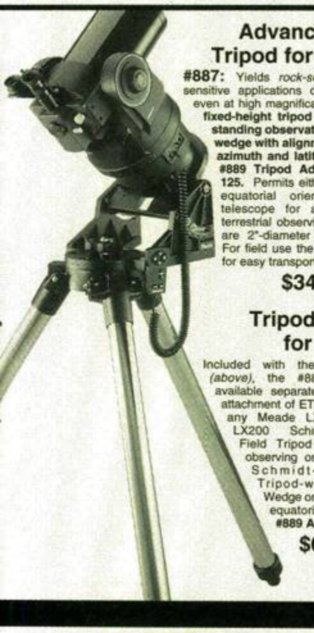
For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, plus optional eyepieces, erecting prism, table tripod, hand controller, *etc.* Includes two steel latches with key.

#774 Case for ETX-90 models: **99.95** (8.58)

#775 for ETX-125EC: **149.95** (13.38)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90 or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics. **$49.95** (3.86)



Advanced Field Tripod for ETX-125

#887: Yields *rock-solid* stability for sensitive applications of the ETX-125, even at high magnifications. **Includes fixed-height tripod convenient for standing observations, equatorial wedge with alignment controls in azimuth and latitude angle, and #889 Tripod Adapter for ETX-125.** Permits either altazimuth or equatorial orientation of the telescope for astronomical or terrestrial observing. Tripod legs are 2"-diameter chromed steel. For field use the tripod collapses for easy transport. **$349.95** (14.00)

Tripod Adapter for ETX-125

Included with the #887 Tripod *(above),* the #889 Adapter is available separately and permits attachment of ETX-125 directly to any Meade LX10, LX50, or LX200 Schmidt-Cassegrain Field Tripod for altazimuth observing or to any Meade Schmidt-Cassegrain Tripod-with-Equatorial Wedge or Superwedge for equatorial applications. **#889 Adapter:** **$69.95** (7.70)

ETX® Deluxe Field Tripod

#883: Custom-designed by Meade specifically for ETX-90 and ETX-125 Astro Telescopes. Tripod height adjusts from 34" to 54", for seated or standing observations. Micrometric controls in azimuth and elevation permit precise polar alignment of the ETX fork mount. Tripod head tilts and locks to 90° for terrestrial applications. Telescope attaches to tripod in seconds with 2 thumbscrews. All-aluminum construction. **$199.95** (10.00)

ETX® Carry Bag

Soft-padded Cordura-type carry bag with shoulder strap; permits storage of any 90mm ETX model, plus table tripod legs, eyepieces, other accessories. **$36.95** (5.26)

NEW!

Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with any ETX model. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus ETX/EC models through the telescope's hand controller.

#1244 Electric Focuser for all ETX-90 models: **$119.95** (6.85)

#1247 Electric Focuser for ETX-125 models: **$119.95** (6.85)

ELECTRONIC CONTROLLER
MEADE

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 570-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

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EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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All Fall Down

As a "meteorite hunter" myself, I greatly enjoyed Tom Yulsman's "In Search of Fresh Fall" (March 2001) about the recent meteorite fall near Portales, New Mexico. However, his claim that Skip Wilson has probably found more meteorites than "any person alive today" is surprising. As a past participant in the Antarctic Search for Meteorites (ANSMET) Program, I've found more than 200 meteorites (but I've never kept an exact count since ANSMET's policy, appropriately, is to assign all the finds to the whole team). More importantly, my contribution pales compared to other long-time ANSMET members.

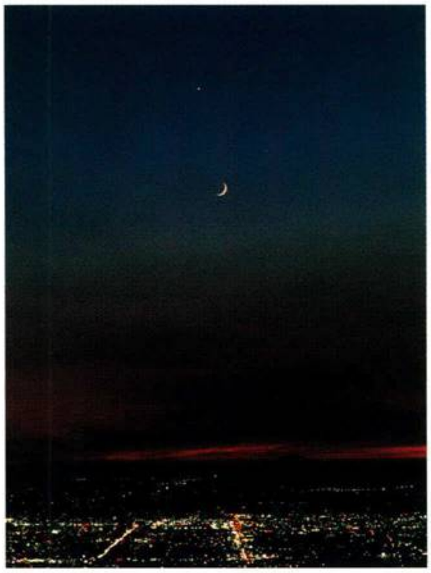
Wilson's contribution is indeed commendable, but don't sell short the contributions of others. — *Scott Sandford, Moffett Field, California*

It was disappointing to once again see the myth of "hot" meteorites perpetuated. On page 51, Fred Stafford reportedly found the meteorite "too hot to handle." After millions of years exposure to the deep cold of space, meteorites heat up only superficially to a depth of just a few millimeters. This is quickly overcome by the dominant mass of extremely cold material composing the object. — *Gary Finiol, Evergreen, Colorado*

Please don't beat the messenger. My sources reported that the meteorite was hot when found. — Tom Yulsman, University of Colorado, Boulder

Unique But Routine?

In the subheading of "Is Earth Unique?" (March 2001) author Martin Rees states, "Odds favor abundant life in the cosmos ... " This is misleading because Rees doesn't sound convinced. Later on, he says, "The emergence of life may be a routine event in the cosmos; on the other hand, it may be hugely improbable ... "



Venus — not a UFO — and the moon overlook El Cajon, California, at sunset. Jerry Schad

Attempts to calculate the probability of life arising on Earth yield extremely low levels of probability — making life on this planet all the more a matter of great wonder and awe. — *Trent R. Logan, El Centro, California*

I must take issue with the following statement by Martin Rees: "If searches for extraterrestrial signals are doomed to fail, proving that Earth were the sole abode of life in our galaxy ... "

Failure to find such signals proves nothing. The number of reputable scientists and science writers who forget the fundamental rule that absence of proof is not proof of absence is horrifying. — *K. A. Boriskin, Bellingham, Massachusetts*

On page 56 Martin Rees writes: "While NASA's hugely expensive manned International Space Station is neither practical nor inspiring ..."

Expensive, yes — but uninspiring? I am willing to bet that there are a lot of folks at NASA and elsewhere who would disagree with that. — *Rich Allen, Wasilla, Alaska*

Venus Skytrap

In March 2001's "Alien Planet," Bob Berman states that Jimmy Carter once saw Venus and reported it as a UFO. Readers can access Jimmy Carter's report at http://users.rcn.com/regulus/small/carter.html. Some portions of the report do not indicate that he (and ten others) were looking at Venus. Descriptions of size, movement, and disappearance of the object question whether it was indeed our brightest planet. — *Jason Blakeslee, Jonesboro, Georgia*

Please print the source of Bob Berman's story about a B-29 squadron trying to shoot down Venus while returning from a bombing mission over Japan. I find that statement a disservice to the memory of the crews who flew those long missions. World War II pilots and navigators — particularly those destined for over-water flying — were thoroughly schooled in celestial navigation.

We used a Mercator projection to measure the altitudes of celestial bodies with an octant and then plotted the lines of position (LOPs). Three LOPs produced a small triangle. That was compared to the course line to ascertain the drift angle. The round-trip distance to Japan and back required careful planning of every last drop of fuel — not much left over for "chasing Venus." — *Robert C. Holt, Jr., St. Louis, Missouri*

With no slight whatsoever to the heroic people who fought, and who still serve, incredible blunders and misidentifications are hardly unique both in wartime and in peacetime.

The original source was an article in Sky & Telescope *magazine more than a decade ago. This account has been repeated in print, in books, and gone through several rounds of fact checking prior to this particular citation.*

Venus's occasionally incredible brightness has fooled countless people

(continued on page 16)

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over the years. Do not assume that everyone who misidentifies this object is a fool or unversed in navigation. As a long-time pilot, I don't fault anyone who is, at least temporarily, fooled by Venus. — Bob Berman

Red Light, Blue Light

The "Discovering Worlds in Transit" (March 2001) illustration on page 42 demonstrates how light shifts toward the blue (shorter) or red (longer) wavelength ends of the spectrum. Were the two captions showing the effect of planetary motion on the spectrum accidentally reversed? — *John Walker, Elko, Nevada*

Actually, no — although the heading directly above each diagram seems counterintuitive at first. As the planet moves backward, the star moves forward — and vice versa. Because planets don't emit their own light, the star's light spectrum shifts. — Astronomy *editors*

No Forwarding Address

Even here in California, we are aware that the Statue of Liberty is not on Ellis Island (March 2001, p. 120), but on Liberty (formerly known as Bedloe's) Island. — *Eugene Kosso, Gualala, California*

You are correct, sir. And we don't think Lady Liberty will be moving any time soon. — Astronomy *editors*

It's Not Easy Being Green

I enjoyed Berman's "Is the Universe Irish," (March 2001) but I thought that green was a combination of blue and yellow, not a primary color. — *Wayne Kyle, Goderich, Ontario*

True enough for pigments, but the additive light wavelengths of stars emit red, blue, and green as primary colors. — Astronomy *editors* ▣

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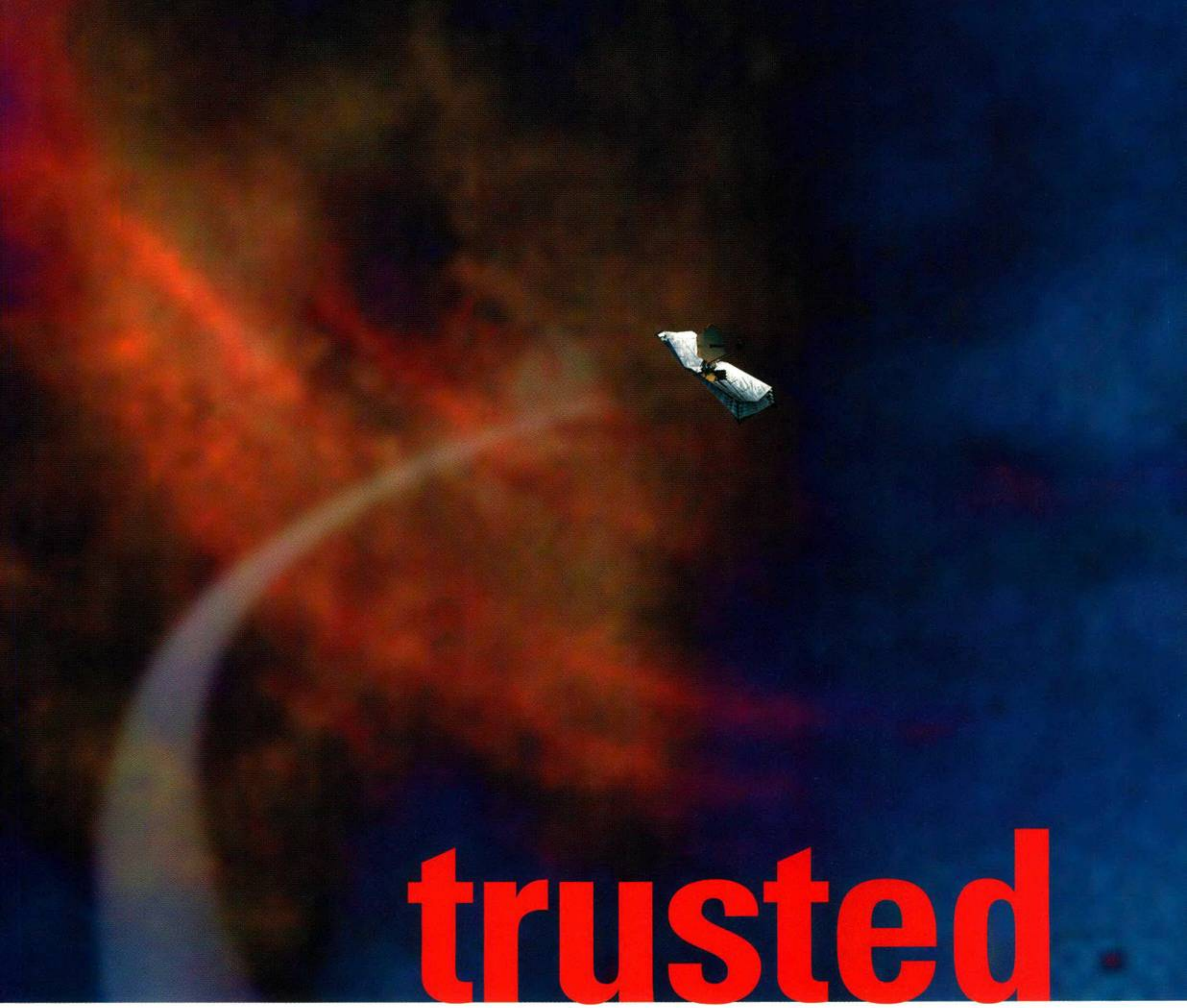

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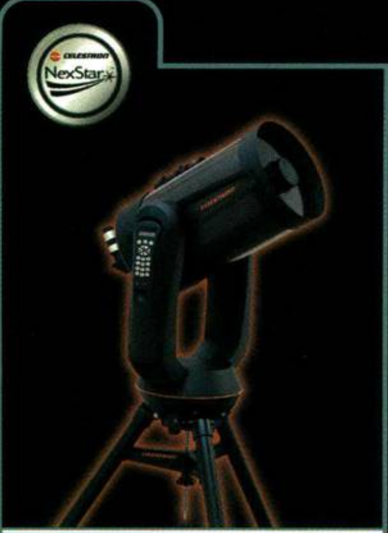

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COMET EVOLUTION

A Trim New Look for the Oort Cloud

▶ If a recent numerical study proves correct, the comets in the Oort Cloud experienced a much more violent past than previously thought. What's more, the cloud — a spherical shell of comets that extends from about 10,000 to 100,000 astronomical units (AU) from the sun — may contain significantly less mass than anticipated.

Astronomers believe that hundreds of Earth masses of icy debris, presumably left over from the formation of the sun, once occupied the same region as the planets Jupiter, Saturn, Uranus, and Neptune. This debris then got ejected by gravitational interactions with those planets and ultimately formed the Oort Cloud. For decades, however, models of the Oort Cloud's formation have included only these and similar gravitational effects.

But new research reveals that these models may have overlooked a key ingredient — collisions among the icy objects in the protoplanetary disk. Alan Stern of the Southwest Research Institute in Boulder, Colorado, and Paul Weissman of NASA's Jet Propulsion Laboratory in Pasadena, California, reported their latest findings in the February 1, 2001, issue of *Nature*.

"I think people typically made the assumption that collisions aren't important, since space is mostly empty, and it's only gravity that really matters," says Stern. "It turns out that's just completely fallacious."

Jerry Lodriguss

The Oort Cloud, a reservoir of comets like the recent visitor Hale-Bopp (seen here), may contain fewer comets than previously thought.

Last year Weissman and Stern sat down to consider whether comet collisions played a role in forming the Oort Cloud. "In two days I convinced myself we were on to something big," says Stern. Early in the history of the solar system, the region of the protoplanetary disk between 5 and 50 AU from the infant sun was densely populated with nascent comets.

The researchers found that collisions among these comets occurred at a much greater rate than the gas giants could eject the comets into the Oort Cloud. These conditions would have prevailed until much of the cometary debris had been pulverized by subsequent collisions and blown away by the sun's radiation pressure.

Collisions continued to win out over ejections until the density in the region dropped significantly. But by this time, the collisions would have considerably depleted the reserve of material available for constructing the Oort Cloud.

"Because collisions introduced additional inefficiencies in the formation of the Oort Cloud, the cloud may be 10 times less massive than previously thought," says Weissman. "By our estimates, it could be as low as about one Earth mass," adds Stern.

The initial reaction to Stern and Weissman's analysis appears favorable. "Their work presents a new wrinkle that definitely has to be taken into account with future simulations of the formation of the Oort Cloud," says planetary scientist Martin Duncan at Queens University in Kingston, Ontario.

Yet the work hasn't been immune from criticism. As Stern and Weissman admit in the *Nature* paper, their model contains two major simplifying assumptions. First, they neglected the possibility that the planets could have scattered some comets into high-inclination orbits, which would take the comets out of the protoplanetary disk for extended periods and thus reduce their chance of collision. Second, they did not include the possible migration of the

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gas-giant planets themselves. Duncan cautions that if Uranus and Neptune migrated outward, as some recent models suggest, it could make a big difference in the results.

Weissman and Stern plan to develop a more sophisticated model, taking these considerations into account, sometime in the next year or two. — WILLIAM SCHOMAKER

SOLAR SYSTEM HISTORY

Space Rocks Bridge the Gap

▶ It isn't often that answers to tough questions simply fall from heaven. But when it comes to understanding the formation of the solar system, astronomers are lucky that prime evidence regularly pelts Earth. The latest examples: two meteorites known as HH 237 and QUE 94411.

Recent microscopic analysis of these two anomalous chondrites — primitive meteorites that contain thousands of tiny spherical particles called chondrules — paints a picture of an early solar system dominated by an immense disk of dust and gas. Add to that powerful bipolar jets that shot from the disk's center, launching material out to planetary distances at speeds approaching hundreds of miles per second.

"Chondrites are the oldest rocks that formed in our solar system," says Alexander (Sasha) Krot, a cosmochemist at the Hawaii Institute of Geophysics and Planetology and lead author of the study that appeared in the March 2, 2001, *Science*. "By studying these components, which we think formed within the first 1 million to 5 million years after the formation of the sun, we can understand what processes took place during this time."

HH 237 and QUE 94411 aren't your run-of-the-mill chondrites. "Most chondrites are only seven to ten percent metal by volume, but these two specimens are about 70 percent iron and nickel," says Anders Meibom, coauthor of the study and a postdoctoral fellow with Stanford University's Department of Geological and Environmental Sciences.

The high metal content of the space rocks, as well as the character of their included metal grains, led the team to conclude that the samples likely condensed right out of the primordial solar nebula at temperatures approaching 3000° Fahrenheit. These results stand in stark contrast to standard models of chondrule formation.

Astronomers believe that normal chondrules formed in the hot (700° F), primordial asteroid belt when precursor materials, such as dust balls, were flash-melted. "The idea is that a lightning bolt or shock wave comes along and zaps these dust balls, raising the local temperature to about 3000° F. The dust ball turns into a droplet, cools fast, and hardens," says Meibom.

"What we are proposing here, however, is a situation in which everything was initially a vapor and then cooled down," he adds. "It's a completely different process that requires much more energy than normal chondrule formation. Such thermal events couldn't *have taken place in the* asteroid belt because there's no energy source for it."

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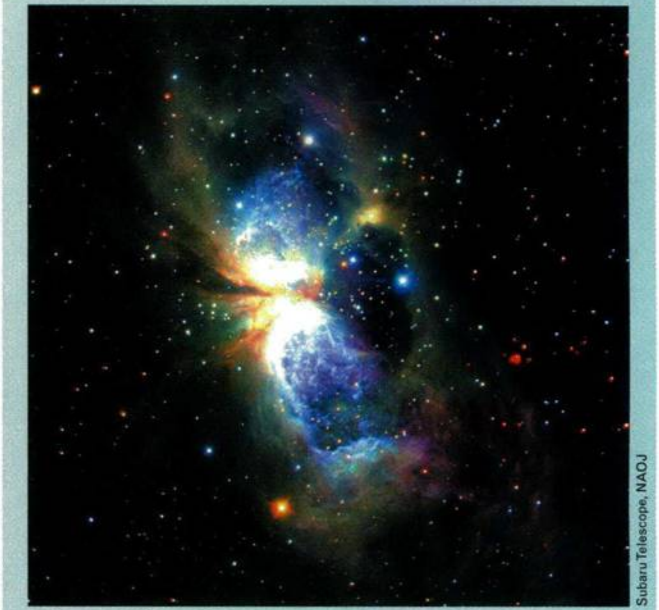
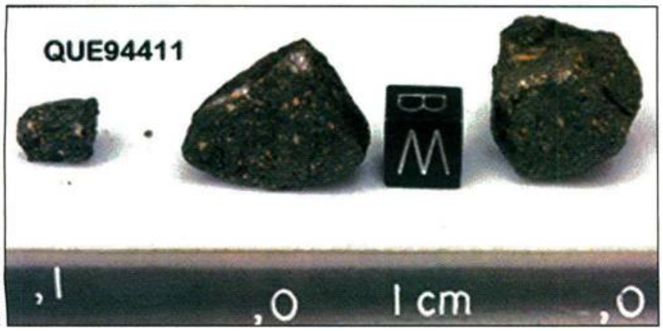


Subaru Telescope, NAOJ

DELICATE STREAMERS highlight the star-forming region known as S106, located 2,000 light-years from Earth in Cygnus. The massive star IRS 4 (Infrared Source 4) lies at the center and helps give the nebula its hourglass shape. A huge disk of gas and dust surrounding the star produces the constriction at the center while material can flow outward more easily perpendicular to the disk. The star itself is about 100,000 years old and contains 20 times the mass of the sun. The image was taken with an infrared camera attached to the 8.2-meter Subaru Telescope on Hawaii's Mauna Kea. A detailed study of the image has revealed hundreds of brown dwarfs — objects having less than 0.08 the sun's mass and thus too small to burn hydrogen like normal stars.



NASA/JSC

Although meteorite QUE 94411, found in the Queen Alexandra Range in Antarctica, measures barely an inch across, it has helped astronomers decipher the beginnings of the solar system.

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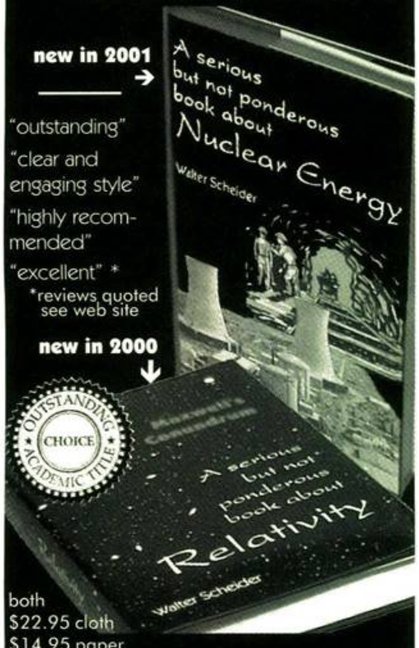
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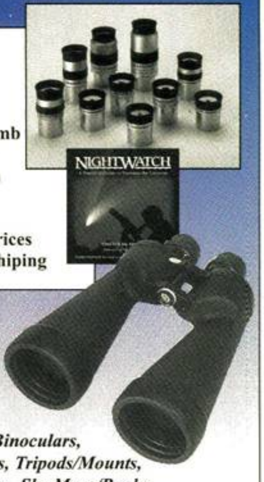
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Based on their microscopic study of HH 237 and QUE 94411, the researchers propose a scenario that goes something like this: Raw chondrule materials present near the inner edge of the protoplanetary disk were vaporized because of their proximity to the infant sun. When large gas bubbles rose toward the surface of the disk and cooled, the chondrules and metal grains condensed. Shortly thereafter, powerful bipolar jets launched these materials toward the outer solar system, with some raining down a few days later at a distance of approximately 140 million miles. There, the materials accreted to form chondrites in the asteroid belt, while the rest went into the formation of planets like Earth and Mars.

University of California astronomer Frank Shu, who developed this disk-wind model of star formation, is pleased with the results. "In these two very special meteorites, we finally have direct evidence that certain portions of rock had to move from some place very hot to some place very cold in a very short period of time," he says. — W. S.

GALAXY EVOLUTION

Collision Forms Giant Clusters

▶ In the world of everyday experience, collisions aren't typically seen as a creative force. Throw a baseball through a window or drive a car into a concrete barrier and you'll be hard pressed to notice anything beyond the shattered glass or the twisted metal.

Far left: Robert Gendler; left: NASA/ESA/Richard de Grijs (Institute of Astronomy)

The starburst galaxy M82 (left, top) collided with its larger neighbor, M81, 600 million years ago. A Hubble shot of M82's central region (above) reveals more than a hundred super star clusters created by the collision.

Galaxies appear to follow a different set of rules. When two galaxies smash into one another, the collision can breathe new life into these formerly staid stellar systems. As huge clouds of interstellar gas and dust crash together, the flames of star formation are stoked far and wide.

Perhaps no object in the local universe illustrates this point better than M82, a bright starburst galaxy visible in backyard telescopes that's located just 12 million light-years from Earth in the constellation Ursa Major.

A new study of M82 conducted with the orbiting Hubble Space Telescope sheds new light on this galaxy's long-ago encounter with its bigger and brighter neighbor, M81. A team of astronomers from Europe and the United States examined the huge star clusters created in the collision and determined that the galactic conflict began approximately 600 million years ago and extended for roughly 100 million years. The team reported their results in the February 2001 issue of the *Astronomical Journal*.

Hubble's eagle eye uncovered more than 100 young, bright, and compact star clusters — each containing roughly 100,000 stars — in the central region of M82. The astronomers concentrated on a sample of these super star clusters that resides in a region appearing to date from the original starburst. By measuring the ages of the stars in these clusters, the researchers could deduce when the collision occurred.

Before the encounter, M82 certainly would not have ranked as much of a star factory. "The last tidal encounter between M82 and M81 about 600 million years ago had a major impact on what was probably an otherwise normal, quiescent disk galaxy," says team leader Richard de Grijs of the Institute of Astronomy in Cambridge, England. "It caused a concentrated burst of star formation in what's called the 'fossil starburst' region. The active starburst taking place today is probably related to debris from M82 itself that has slowly rained back on the galaxy since the interaction with M81."

The super star clusters appear to be unlike any seen in our galaxy. De Grijs argues that they are young globular clusters, an oxymoron when applied to the Milky Way because all of our globulars formed more than 10 billion years ago with the birth of the galaxy. These spherical collections contain anywhere from tens of thousands up to a million stars. Young, massive clusters similar to those in M82 appear in some other galaxies, and those galaxies also show signs of having experienced an encounter in the not-too-distant past.

"Our results support other observations, mostly made with Hubble, that the formation of globular clusters continues today," says de Grijs. "In our opinion, this has been one of Hubble's main contributions to astrophysics."
— Richard Talcott

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(Hint: Download a FREE trial version of Starry Night at www.StarryNight.com and cheat.)

1. The "Trifid" is a what?
- a. Galaxy
- b. Nebula
- c. Globular Cluster
- d. B-movie monster

2. What is the most distant object you can see with the naked eye?
- a. Pluto
- b. The Andromeda Galaxy
- c. Crab Nebula
- d. Isn't that against the law?

3. What are globular clusters?
- a. Space dust
- b. Twin asteroids
- c. Balls of closely packed stars
- d. Mom's Awful Cookies

4. Comet Halley is visible from Earth once every how many years?
- a. 52
- b. 24
- c. 76
- d. Hup, Hup, Hup

5. Galilean moons orbit which planet?
- a. Mercury
- b. Jupiter
- c. Hollywood

6. The sun travels through how many constellations in one year?
- a. 6
- b. 12
- c. 13
- d. The sun moves?

7. Where is M31?
- a. Andromeda
- b. Perseus
- c. Near Chicago

8. What is another name for the North Star?
- a. Polaris
- b. Sirus
- c. Celine Dion

9. Which of the following isn't a nebula?
- a. Crab
- b. Orion
- c. Moose

Answers:
1(b), 2(b), 3(c), 4(c), 5(b) 6(c), 7(a), 8(a), 9(c)

2

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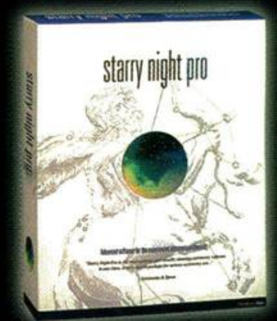

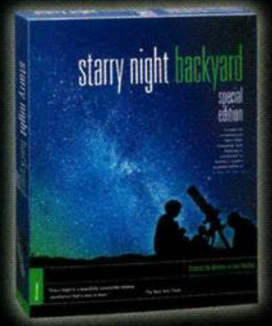

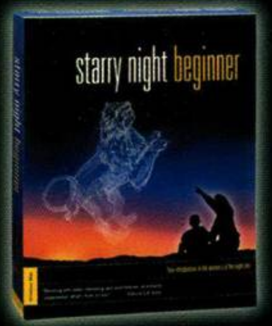

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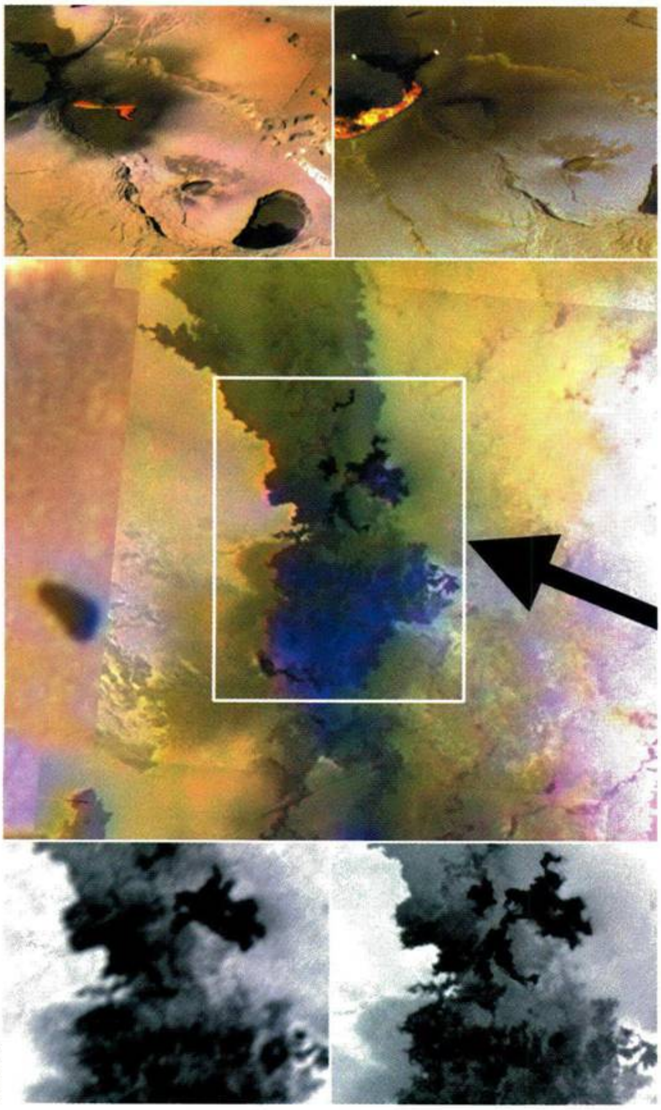

NASA/JPL

Major changes occurred in the ongoing eruption at Io's Tvashtar Catena over a three-month span (left, top). At the Amirani lava fields (middle), nearly two dozen new flows appeared during a 4½-month period (bottom).

GALILEAN MOONS

Io's Volcanoes: A Rush to Erupt

▶ Jupiter's volcanically active moon Io has a case of hyperactivity that even Ritalin would have a tough time controlling. While some of the moon's volcanoes undergo massive eruptions spaced many years apart, others seem to erupt continually, presenting a different face almost every time they're observed. Although planetary scientists have known about this activity since the Voyager missions flew past in 1979, it's taken the orbiting Galileo spacecraft to monitor the rapid changes on Io.

One especially dynamic eruption occurred at a chain of volcanic bowls named Tvashtar Catena. Between November 1999 and February 2000, Galileo saw a major movement of the hot lava in that region. Planetary scientists were ecstatic over the fortuitous observations — this style of volcanism remains too unpredictable and short-lived to make meaningful photographic plans.

Even more impressive are changes seen around the Amirani lava flow, the largest active lava flow in the solar system. Planetary scientists identified 23 distinct new flows by comparing images taken in October 1999 and February 2000. The Amirani lava-flow field spans about 200 miles, with individual flows each stretching several miles. In the 4½ months between images, the new flows covered 240 square miles.

Galileo scientists studying Amirani are trying to understand what creates such huge lava flows. The last eruption of this size on Earth occurred 15 million years ago along the Columbia River in what's now the state of Washington. Many Earth scientists thought that only violent eruptions could have created the Columbia River basalts, but the Amirani eruption is fairly calm — even though it disgorges 100 tons of lava each second.

Galileo's discoveries should continue for another couple of years, now that NASA has extended the mission once more. The imaging part of the mission will wrap up later this year, after one last flyby of Callisto and two of Io. In 2002, the spacecraft will concentrate on the planet's huge magnetic field and dip to within 300 miles of the inner moon Amalthea. Finally, in August 2003, Galileo will plunge directly into Jupiter, burning up as it plows through the planet's massive atmosphere. — R. T.

GALACTIC ASTRONOMY

On the Trail of Lithium

▶ Astronomy is rife with unsolved mysteries, some newer than others. The origin of the Milky Way Galaxy's lithium — the third element on the Periodic Table — has puzzled astronomers for decades. But a group of sky-watching gumshoes, determined to crack this mystery, reopened the case file last year. Much to the delight of astronomers, Catherine Pilachowski of the National Optical Astronomy Observatories in Tucson, Arizona, announced in January that she and her colleagues have uncovered the source for at least some of the galaxy's lithium.

Current theory suggests that at least 10 percent of the Milky Way's lithium was forged during the Big Bang. Determining the source of the remaining 90 percent, however, has proved harder than finding the remains of the *Titanic.* Although astronomers long suspected that some yet unknown stellar process created this lion's share of galactic lithium, the process and type or types of stars responsible remained elusive — until now.

Using the 3.5-meter WIYN Telescope at Kitt Peak National Observatory in Arizona, Pilachowski's team surveyed hundreds of red giant stars in more than a dozen globular clusters in an attempt to divine the missing source. They discovered that a small fraction of red giants — about 12 of the nearly 700 they observed — actually produce relatively high concentrations of

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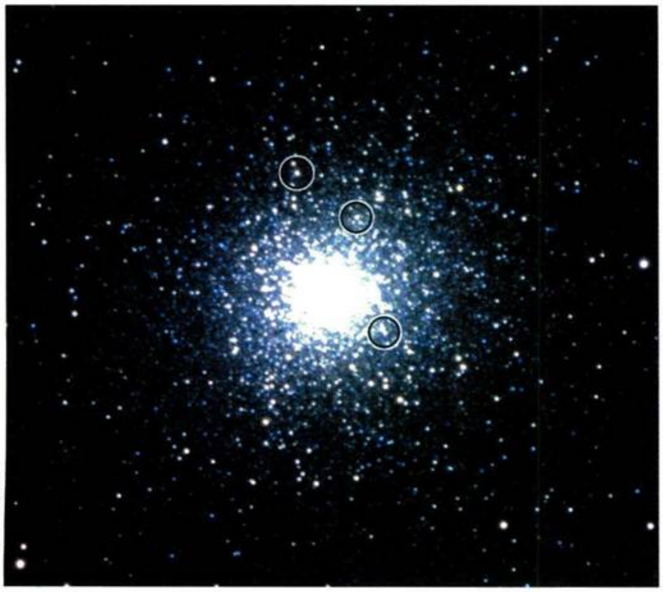


AURA/NOAO/NSF

Globular cluster M13 holds three red giants (circled) that proved to be unexpected sources of lithium.

lithium. "Our results suggest that fresh lithium has been produced within the stars themselves," explains Pilachowski.

In many ways, however, the observations raise as many questions as they answer. Stars consume much of their lithium reserves in the hydrogen-burning phase of their existence. When a star exhausts the hydrogen fuel in its core, the outer layers of the atmosphere expand and the star becomes a red giant. Material in the upper layers of the atmosphere then mixes with that in lower layers through convection, with a motion similar to that of a boiling pot of soup. Any remaining lithium is quickly burned as it's transported and exposed to the high temperatures of the stellar interior.

So, red giants shouldn't have much lithium, and most don't. Pilachowski's team found lithium only in very bright and bloated red giants (500 times as luminous as the sun and 30 times as big) — those on the cusp of igniting helium in their cores.

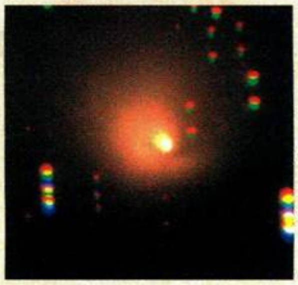
The researchers suggest that the lithium owes its existence to the same mixing process that's accused of depleting it. Although lithium gets destroyed in stellar interiors, stars can produce a radioactive isotope of beryllium (beryllium 7) that decays to an isotope of lithium (lithium 7). The researchers believe that the mixing mechanism brings beryllium 7 to the surface and accounts for the temporary presence of lithium.

Pilachowski estimates that about six percent of bright red giants in globular clusters contain lithium. Still, she cautions that her team's observations don't necessarily explain the production of all the Milky Way's lithium.

"It may be that the galaxy's lithium cannot be attributed to a single origin," warns Pilachowski, "but rather is produced in several different environments, each contributing partially to the lithium content of the Milky Way." — W. S. ◼

Hale-Bopp Checks in, Long Distance

Although it's been four years since Comet Hale-Bopp graced our sky, the brightest comet of the past 25 years has not faded from our memories. Fitting, then, that it has yet to fade from view. Despite lying some 1.2 billion miles from the sun — well beyond the orbit of Saturn — the comet still appears active. Astronomers using the European Southern Observatory's 2.2-meter telescope at La Silla, Chile, captured the comet in late February and early March. The resulting image shows that enough sunlight hits the comet's dirty-snowball nucleus to liberate gas and dust, forming an enormous coma and a curved jet. Nearby stars appear as several multi-colored dots because the comet moved between individual images, which were taken through different filters.



European Southern Observatory

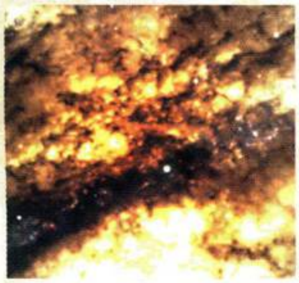
Comet Hale-Bopp stays active a billion miles from the sun.

Brown Dwarf Glows with Radio Waves

A group of students took a long-shot gamble and hit the jackpot, detecting radio waves from a brown dwarf. No one expected brown dwarfs, objects bigger than a planet but smaller than a star, to emit noticeable radio waves. But graduate student Edo Berger of Caltech led a student team that decided to examine the brown dwarf LP 944–20 with the Very Large Array radio telescope. Known to flare in x rays, LP 944–20 apparently does in radio waves as well, emitting 10,000 times more energy than any astronomer expected. The surprising discovery will likely force experts to rethink their theories about magnetism in brown dwarfs.

Huge Black Hole Lurks in Centaurus A

Astronomers seem to find big black holes at the center of nearly every galaxy. The latest belongs to Centaurus A, a peculiar galaxy 11 million light-years from Earth. A team of astronomers led by Ethan Schreier of the Space Telescope Science Institute viewed the galaxy with the 8-meter Very Large Telescope in Chile. The team penetrated the galaxy's thick dust lane by observing in the infrared. Spectra of the galaxy's core show a gaseous disk rotating rapidly around a dark mass concentration. The team thinks a supermassive black hole with 200 million times the mass of the sun best explains the observations.



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Centaurus A apparently harbors a giant black hole at its center.

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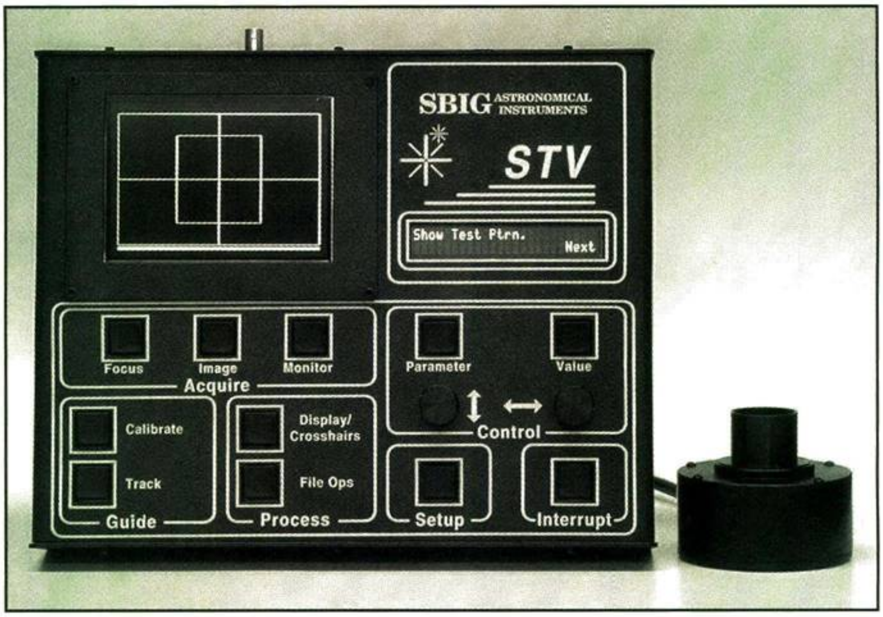
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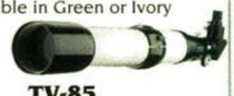

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B)

C)

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E)

F)

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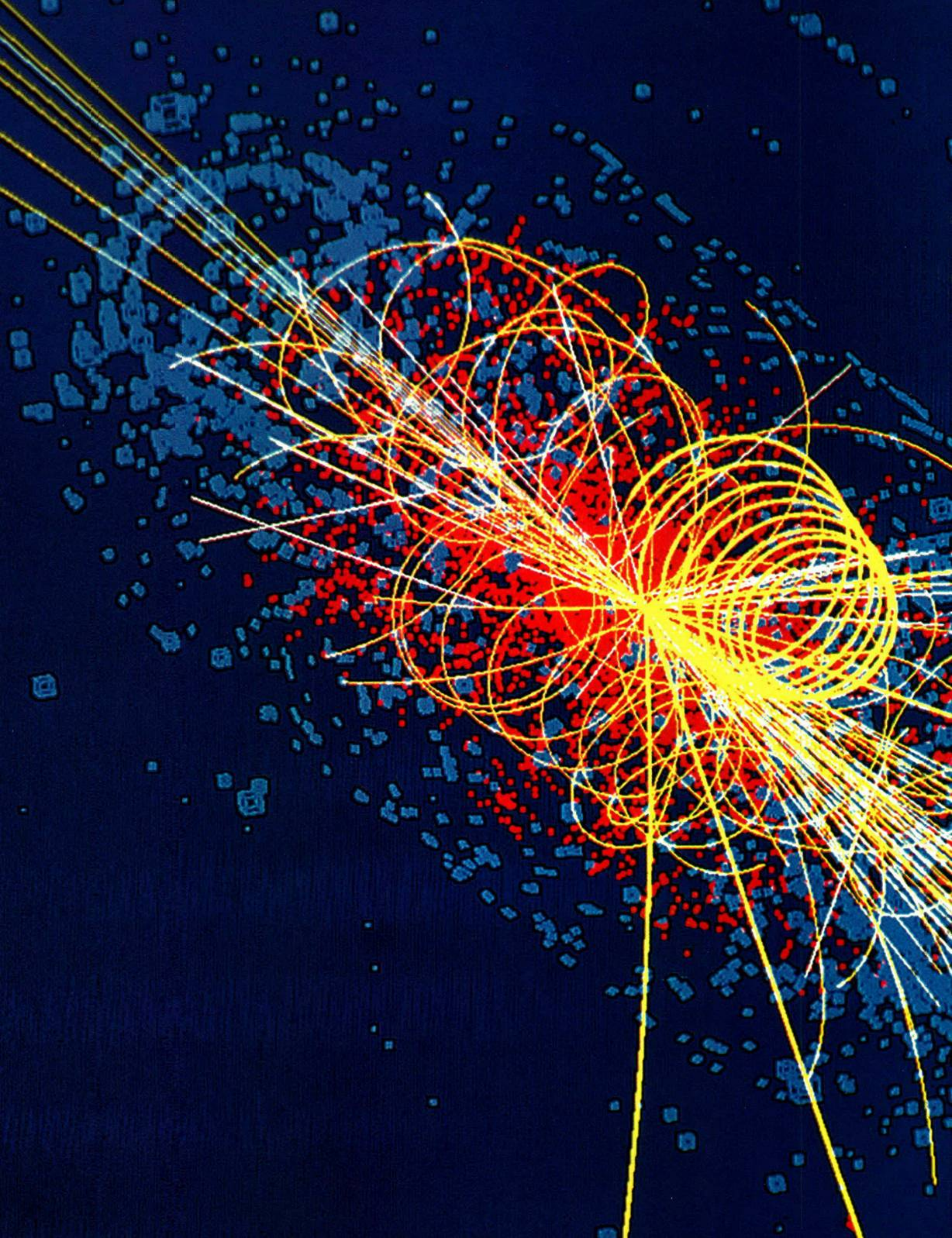
Inner Space and

In the early 1980s, cosmologists realized that the theories that might unify particle physics relate to the earliest moments of the universe. In recognition of the mutual interests of cosmologists and particle physicists, University of Chicago cosmologists Michael Turner and Edward W. "Rocky" Kolb organized a conference in 1984 titled "Inner Space, Outer Space: The Interface between Cosmology and Particle Physics." Since that meeting, astronomy has benefited from the collaboration of cosmologists and particle physicists. For example, the consensus among the members of both academic camps is that the bulk of all matter in the universe probably exists as slowly moving elementary particles. Also, tiny quantum fluctuations occurring on subatomic scales were magnified by the infant universe's incredible expansion to become clusters of galaxies and other large-scale structures. Of course, the new understanding has generated new questions — questions that would have been unimaginable a century ago. In acknowledgement of how far we've come in the past two decades and how far we have yet to go, *Astronomy* explores in this special issue the many fascinating connections between inner space and outer space.

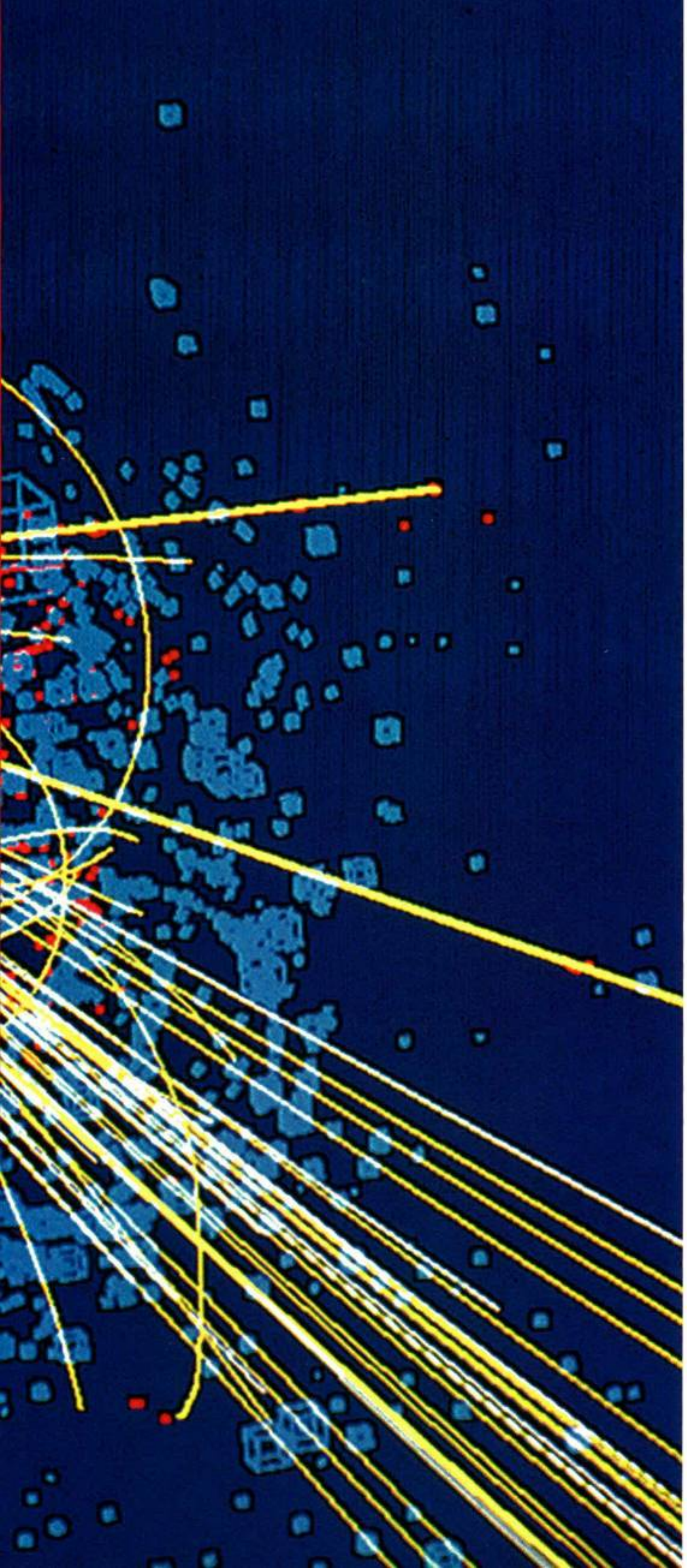
Outer Space



INSIDE-OUT COSMOLOGY

The answers to some of cosmology's greatest mysteries may lie in subatomic particles that exist only as theoretical inventions.

by Robert Zimmerman



Immiscible as oil and water, cosmologists and particle physicists have, until recently, happily ignored each other. After all, they work in separate buildings and speak different scientific languages. Cosmologists are apt to speculate, dabble in philosophy, and give public lectures. Particle physicists tend to be mathematical monks with floor-to-ceiling blackboards and chalk dust under their fingernails.

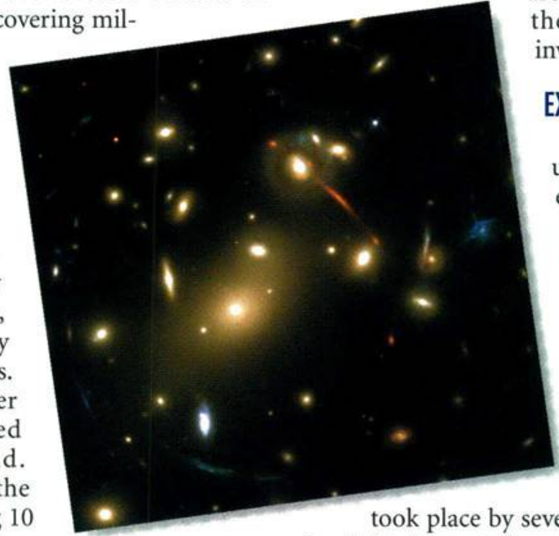
The two camps might not admit it, but they also embrace radically different superheroes. The cosmologists favor Mego, who, bigger than life and garishly clad, voyages to the outer reaches of the cosmos making spectacular discoveries on the large-scale structure of the universe. Particle physicists are personified by Micronaut, who, studious and bespectacled, probes the strange Lilliputian world inside atoms where everyday trifles such as telescopes and gravity are irrelevant. Mego gets more publicity; Micronaut wins more Nobel Prizes.

This computer simulation of the decay of a Higgs boson shows four muons (yellow), and energy deposits (blue). CERN

ALIEN WORLDS

The 20th-century explorations of Micronaut have taken him deep within atoms, where he flits among electrons circling nuclei of tightly bunched protons and neutrons. It is an alien, high-energy setting for characters that Steven Spielberg could have named — quarks, leptons, bosons, and other oddball particles. Down here, the strong nuclear force is 10^{39} times greater than gravity on Earth's surface, clenching atomic nuclei in a crushing grip. Electrons glide on electromagnetic fields, and other subatomic particles, if visible at all, seem to flee before Micronaut's eyes, changing form even as he gazes at them.

Meanwhile, Mego flies outward into space where cosmologists' 20th-century explorations have revealed billions of galaxies strewn in gigantic clusters covering millions of light-years. Mego's exploits were made possible by a revolution in telescope technology, which began with construction of the 100-inch Hooker Telescope at Mount Wilson and the 200-inch Hale Telescope on Mount Palomar. Two generations of astronomers, led by Edwin Hubble and Allan Sandage, used the telescopes to carefully examine the structure of the cosmos. Telescopes have gotten even bigger and digital cameras have boosted their power more than 100 fold. Everything is moving apart as if the universe was born in a hot Big Bang 10 to 14 billion years ago.



Stepping on the shoulders of Hubble and Sandage, two teams of astronomers, led by Brian Schmidt of the Mount Stromlo and Siding Spring Observatories in Weston Creek, Australia, and Saul Perlmutter at the Lawrence Berkeley National Laboratory in Berkeley, California, have found strong evidence that the expansion of the universe is actually accelerating due to a mysterious force called dark energy. Thanks to the many gorgeous and telling images produced by the Hubble Space Telescope, the Cosmic Background Explorer (COBE) satellite, and other ground-, balloon-, and space-based instruments, the world is familiar with the observations of astronomers and the interpretations of their theoretical cousins, cosmologists.

PARALLEL UNIVERSES

Almost unnoticed by nonscientists is the pattern of parallel discoveries in the past two decades involving cosmology and particle physics — discoveries that raise fundamental new questions for which cosmologists and particle physicists are cooperatively searching for answers.

"Progress in cosmology and progress in understanding elementary particles are now inextricably tied together," says Michael Turner, a particle-physicist-turned-cosmologist at the University of Chicago and chief spokesmen for the collaboration. "No longer can we study one or the other in isolation." Paul Steinhard, a Princeton University astrophysicist and member of both camps, says,"I walk around with a perpetual smile on my face, because I feel as if I can't lose."

For example, cosmologists have powerful indirect evidence that 30 percent of the matter in the universe exists as unknown particles called cold dark matter. (See "The 8 Greatest Mysteries of Cosmology," page 46.) Astronomers have detected the invisible cold dark matter by its gravitational effects on the motion of stars in galaxies and the bending of starlight passing through it. In 1989 experiments at the Stanford Linear Accelerator Center (SLAC) in California and the European Laboratory for Particle Physics (CERN) in Geneva, Switzerland, particle physicists strengthened the argument that cold dark matter exists as elementary particles left over from the Big Bang. Actually identifying the particles of cold dark matter, which form halos around galaxies and clusters of galaxies, is one of the biggest challenges of science today. Particle physicists and cosmologists are using every technological trick at their disposal to catch sight of the invisible stuff.

EXPLORING THE BIG BANG

The hot Big Bang theory is undoubtedly one of the greatest scientific triumphs of the 20th century. It provided an explanation for much of what telescopes reveal — the universe began as a hot, dense soup of fundamental particles. "As the universe expanded and cooled," says Turner, "layer upon layer of structure built up. At around 10^{-5} second, neutrons and protons formed from quarks. In a series of well-understood reactions that took place by several hundred seconds, the nuclei of a few light elements formed, and by 300,000 years the universe had cooled sufficiently so that the nuclei and electrons could combine to form atoms."

This 300,000-year boundary is like the bark on a tree that protects the wood underneath. No telescope can see beyond this boundary because before that time the universe was opaque. However, particle accelerators have become a kind of time machine that can penetrate the universe's innermost growth rings. How? By colliding particles together at energies that generate the primordial soup of particles that fleetingly existed moments after the Big Bang. For example, the Fermi National Accelerator Laboratory in Illinois takes scientists to within 1-billionth second of the Big Bang.

From the results of Fermilab, CERN, SLAC, and other accelerators in the United States, Germany, and Japan, scientists hope to find the Holy Grail of particle physics — a theory that explains the relationships between all subatomic particles and the four known forces of nature — the strong and weak nuclear forces, electromagnetism, and gravity. This Holy Grail eluded Einstein and others ever since Ernest Rutherford first determined the basic structure of the atom in 1911. Cosmologists are using particle accelerators to search for their Holy Grail — an improved Big Bang theory that explains how the universe began and evolved into what the cosmos looks like today.

MICRONAUT'S WORLD

By the 1930s, physicists had agreed that atoms are made of protons, neutrons, and electrons. In the 1950s, this tidy picture was complicated by the discovery of more subatomic particles. By crashing electrons and positrons or pairs of other subatomic particles together in accelerators, physicists learned that the diminutive electron belonged to a six-member family of light particles called leptons. The leptons are the electron, muon, tau — and their neutrinos; the electron neutrino, muon neutrino, and tau neutrino. (Each lepton, like other subatomic particles, has a corresponding antiparticle that has the same mass and properties of its analogous particle, but with opposite charge, magnetic properties, or coupling to other fundamental forces.)

Physicists also discovered that protons and neutrons belonged to a family of heavy particles called baryons. Furthermore, they found another group of particles — mesons, which are lighter than the baryons. Micronaut's world was getting cluttered.

In 1963, Caltech physicist Murray Gell-Mann had a "eureka" moment when he came up with the idea that baryons and mesons are made of more fundamental particles: quarks. By giving quarks and antiquarks either one-third or two-thirds of a unit charge, Gell-Mann could mix and match them to produce protons, neutrons, and mesons. His theory predicted the existence and properties of other subatomic particles, which were later discovered. Quark masses range from 10 million to 175 billion electron volts, while leptons range from the nearly massless electron neutrino to the tau, 1.78 billion electron volts. (Because energy and mass are equivalent, physicists use a unit of energy — the electron volt — to measure the mass of tiny particles.)

Gell-Mann's discovery of the quark also allowed him and his colleagues to put all elementary particles into just three groups — quarks, leptons, and gauge bosons. Physicists have organized these particles and the four fundamental forces into a framework called the Standard Model. Unfortunately, the model is incomplete. For example, it can't explain why the strong nuclear force is 100 times more powerful (at subatomic distances) than electromagnetism, 10 trillion times more powerful than the weak force, and 10^{39} times more

Background galaxies "lensed" by Abell 2218 (left) show that the galaxy cluster contains cold dark matter. NASA, A. Fruchter, and the ERO Team

The Big Bang theory doesn't fully explain how the early homogeneous universe became inhomogeneous (below). R. Williams (STScI), HDF-STeam, and NASA

Black holes inside large galaxies (above) are particle accelerators with vastly more power than any accelerator on Earth. AURA, STScI, and NASA
Electron-positron collisions at CERN in 2000 resulted in events, such as this one (right), compatible with production of a Higgs boson. CERN

powerful than gravity. The Standard Model, while a great achievement, also doesn't explain why nature produces so many subatomic particles. "There must be something grander than the Standard Model that unifies all of these forces and particles," says Turner.

His wish, which is the dream of many physicists, has been slowly falling into place ever since Scottish physicist James Clerk Maxwell developed a set of equations in the 1860s and 1870s that brought electricity, magnetism, and light into a single set of relations. Another important step came in the early 1970s when American physicists Steven Weinberg and Sheldon Glashow, the Pakistani physicist Abdus Salam, and others demonstrated a link between the weak nuclear force and the electromagnetic force: They called it the electroweak force. Experiments at CERN in the 1980s supported the ideas of the electroweak force. That set the stage for a grander theory to combine the strong and electroweak forces.

Another mystery of the Standard Model is how particles get their masses. The favored picture was devised by physicist Peter Higgs of the University of Edinburgh in the late 1960s. He introduced a new field — the Higgs field — and its associated particle, the Higgs boson. The theoretical Higgs boson is analogous to gauge bosons, the fundamental particles in the Standard Model that "carry" the four known fundamental forces between other particles. As particles move through the Higgs field their interaction with it would produce their mass. It's as if you are trying to walk through a pool of water, and as you move through it, the resistance to your motion is a measure of your mass/energy.

To historians of astronomy, the Higgs field sounds a lot like the discredited "ether" that theorists of the 19th century believed permeated the universe.

In the mid 1980s, others suggested a bolder approach called string theory. It would unify the four fundamental forces, thereby filling in the gaps of the Standard Model. According to string theory, the most fundamental particles are not particles at all, but incredibly small strings that exist in a 10-dimensional universe. For unknown reasons, only the three familiar spatial dimensions and the time dimension are discernable to us. "The extra dimensions of space in string theory is another setting to explore cosmological scenarios," says Princeton's Steinhardt. "But string theory still isn't well enough understood that you can test it."

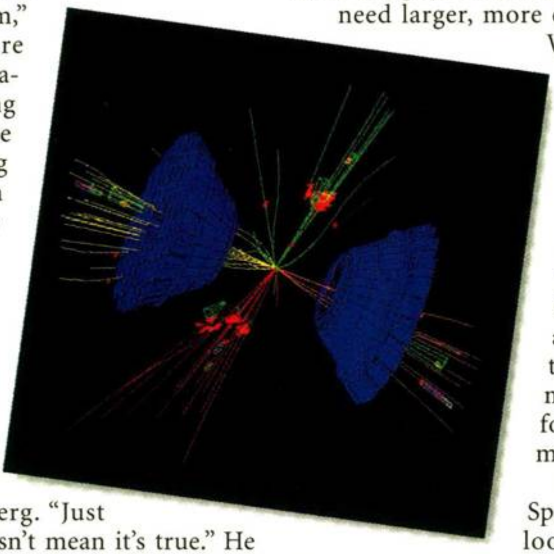
An aspect of string theory, called supersymmetry, is almost as bold as string theory itself. Supersymmetry is based on spin, a physical property that all subatomic particles have to some degree. Physicists have found that all subatomic particles belong to only two spin families, designated fermions (particles with half-integer units of spins, such as electrons, protons, and neutrinos) and bosons, (the force particles). The supersymmetry model, which many theoreticians embrace because of its mathematical beauty, leads to yet a new family of "superpartner" particles.

WHAT'S THE (DARK) MATTER?

Not only might superpartner particles be detectable in particle accelerators, it could happen within a few years. One superpartner particle is the neutralino. Neutralinos have deep significance to cosmologists because supersymmetry theory predicts they are superabundant and have masses between 40 and 400 billion electron volts. With such ubiquitous, high-mass particles existing throughout the universe, neutralinos could be the invisible cold dark matter that holds galaxies and other cosmic structures together.

Using a variety of novel techniques, more than two dozen experiments are either in operation, being built, or are in development to search for neutralinos. "There is a heated race to find them," says Turner. "Particle physicists are trying to make neutralinos in accelerators, and cosmologists are building special observatories to detect the neutralinos left over from the Big Bang. I hope both groups find them because then you will have a more believable story."

However, since no direct evidence for supersymmetry exists, some physicists doubt neutralinos will be found and consider the theory unnecessary. "I have quite a few lingering doubts, based on pure theoretical prejudice, about whether supersymmetry exists," says MIT physicist Leslie Rosenberg. "Just because something is beautiful doesn't mean it's true." He and other supersymmetry skeptics prefer other extensions of the Standard Model to resolve its various problems.



Another hypothetical particle being sought by physicists and cosmologists is called the axion. Theorized to be much lighter than a neutralino, with a mass at least slightly larger than 1-millionth of an electron volt, axions were invented to explain why the strong nuclear force does not always behave as predicted by the Standard Model.

If the axion does exist, it also would be an ideal cold-dark-matter candidate. However, nature has given axions a Catch-22 property. The couplings of such a diminutive particle to other forms of matter would be so vanishingly weak that they may be virtually undetectable. At the same time, axions would have been produced so abundantly in the Big Bang, and their existence — like that of neutralinos — may also help explain the expansion of the universe. Experiments in the United States and Japan are attempting to tickle the axion to decay inside ultrasensitive detectors, but none of the particles have been found so far.

Meanwhile, the hunt for the Higgs boson is heating up. For cosmologists, the discovery of this particle and its accompanying Higgs field would directly impact two of their biggest mysteries — inflation of the universe after the Big Bang, and dark energy that is causing the expansion of the universe to accelerate. If the Higgs field exists, physicists will use its properties to describe the vacuum of space, which in turn will make it easier for cosmologists to explain how the universe inflated in its earliest moments and why its expansion is accelerating billions of years later.

One experiment, the Large Electron Positron (LEP) collider at CERN, recently detected "a number of events compatible with a Higgs boson production." Since LEP was barely able to make this detection in 2000, confirmation of the discovery requires the construction over the next five years of an upgraded collider. In the mean time, physicists at Fermilab's upgraded Tevatron, currently the world's highest-energy accelerator, will have a clear shot during the next five years at finding the Higgs boson, if it exists at the mass predicted by earlier experiments.

COSMOLOGICAL CONVERGENCE

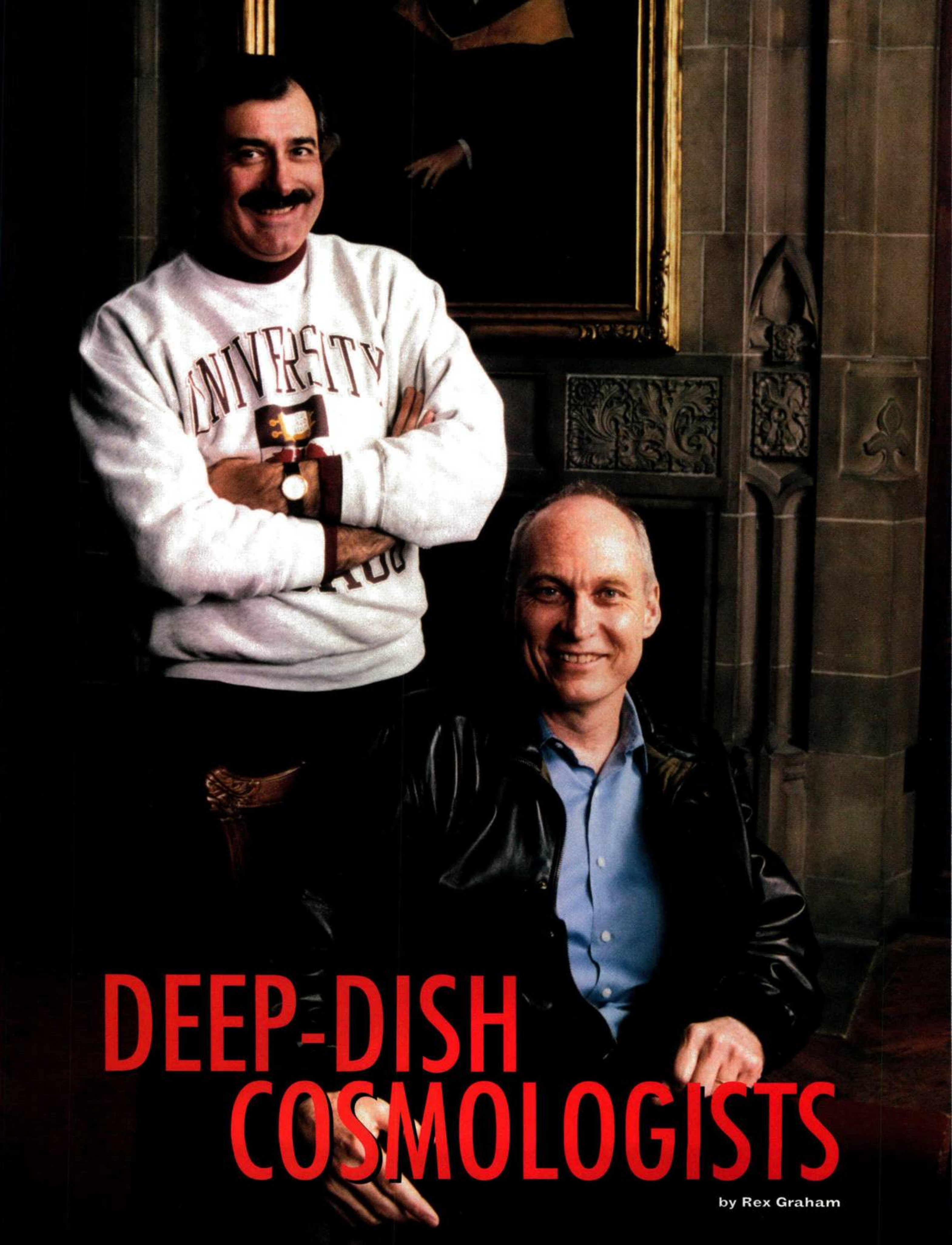
If neither axions, neutralinos, nor Higgs bosons exist, however, physicists and cosmologists will be in a theoretical bind. For physicists to refine the Standard Model, they will need larger, more expensive colliders and detectors. Without them, their only option will be to join cosmologists and look up to the heavens.

"Dark energy can't be created in an accelerator, and accelerators alone are not going to take physicists from the Standard Model to a unified theory," says Turner. "So particle physicists and cosmologists must have a partnership. With accelerators and telescopes working together, particle physicists and cosmologists can discover how all the forces and particles of nature ultimately fit together."

NASA's Gamma-ray Large Area Space Telescope (GLAST), designed to look for exotic particles created by black holes, will reach orbit in 2005. In a display of cooperation between Mego and Micronaut, physicists at SLAC are building the detector for GLAST.

So, while cosmologists look to Micronaut to do inside-out cosmology, physicists gravitate to Mego to conduct outside-in experiments. At the dawn of the 21st century, it looks as if the answers to some of the universe's greatest mysteries may reveal themselves — inside and outside.

Robert Zimmerman is a regular contributor to Astronomy. *Co-winner of the first David N. Schramm Award for High Energy Astrophysics Science Journalism, he is the author of* Genesis: The Story of Apollo 8: The First Manned Flight to Another World.



DEEP-DISH COSMOLOGISTS

by Rex Graham

If there were a Smithsonian Museum for cosmology, one of its exhibits should include the family room of a split-level house on Glen Drive in Warrenville, Illinois. During the mid 1980s, the house in this Chicago suburb, owned at the time by Michael Turner, functioned as an Underground Railroad for aspiring cosmologists. The underground gathered Monday nights for six years in the family room of the house. Driven by a passion for cosmology, Turner and his co-host and partner Edward W. "Rocky" Kolb led discussions there about everything from the Big Bang to how the same laws of physics that control the structure of the cosmos also mold the inner world of atoms.

Today, the two cosmologists are near the top of astronomy's academic hierarchy, but two decades ago they struggled to gain altitude. Skeptics complained that the ideas of cosmologists such as Turner and Kolb were closer to metaphysics than physics. However, University of Chicago astrophysicist David Schramm and particle physicist Leon Lederman convinced NASA in 1983 to provide initial funding for a cosmology-research group at the Fermi National Accelerator Laboratory in Batavia, Illinois. Fermilab physicists accelerate subatomic particles to nearly the speed of light and collide them together to produce fleeting showers of elementary particles that roamed free in the primordial universe. Schramm and Lederman wanted to throw a few cosmologists into the academic fray at Fermilab and they recruited Turner, then an associate professor of astronomy and astrophysics at the University of Chicago, and Kolb, then a theoretical physicist at Los Alamos National Laboratory in New Mexico, to head the group. "They just brought us in and said, Go to it, boys," says Turner.

Pizza parties thrown by two fun-loving cosmologists became academic feasts for the lucky participants

The "Cheech and Chong of cosmology" wore blue jeans, owned few neckties, and found Fermilab stuffy. To this day, Kolb dons costumes while lecturing students at the University of Chicago where he teaches part-time. Turner eschews suits in favor of dark slacks and a black leather jacket.

Monday nights at Turner's house about five miles southeast of Fermilab became cosmological jam sessions. There was always plenty of pizza. Turner and Kolb would begin by tossing witty jibes like circus daggers at each other as a prelude to discussing the birth of the universe. Turner dubbed the once-a-week gatherings "Primordial Pizza."

"It was the early, go-go, junk-bond days of cosmology," says Turner, who now has Schramm's old job as chairman of the Astronomy and Astrophysics Department at the University of Chicago. (Schramm died in 1997 when the plane he was piloting crashed in Colorado.) "In one night of Primordial Pizza, we'd speculate up one wall and down the other, working through 10 different models of the universe."

The speakers at Primordial Pizza — eager, brilliant graduate students, postdoctoral fellows, and faculty members at universities — experienced nothing like it before or since. Simply reading the title of their presentations often resulted in a barrage of questions. Scientists who only hours before had received courteous receptions during their Fermilab talks were aghast. Speakers relied only on a blackboard, one piece of chalk, and their wits. Sometimes, two speakers shared the chalk like tag-team wrestlers.

Lederman, who won a Nobel Prize in physics in 1988, rarely attended. But Schramm, an expert on the Big Bang, usually stood at the bar ingesting pizza, asking questions, and probably fearing and enjoying what he had created. If Turner and Kolb were the bad boys of cosmology, Schramm was its respectable godfather. "The real key of Primordial Pizza was its informality," says Fermilab astrophysicist Joshua Frieman, who once attended as an astronomy graduate student. "I learned the importance of bouncing ideas off people. Today, students see fancy PowerPoint presentations and get a glossy, superficial sense of what's going on."

Papers and ideas discussed at Primordial Pizza were subjected to "completely unedited, honest criticism," says Turner. "Nobody would politely disagree. Would you rather hear it from us, or from a journal referee?" Some attendees felt overwhelmed when equations overflowed the blackboard. Someone suggested that ultrahigh-energy cosmic rays (energetic particles that travel at close to the speed of light and bombard Earth's atmosphere from all directions) originate from something called cosmic strings. The next day, group attendees began collaborating on a paper for publication in a scientific journal. Papers in *Science* often were shredded in Warrenville, forming the basis for a rebuttal written by Primordial Pizza attendees. "Some people called it ambulance chasing," says Turner. Like no other place in academia, Primordial Pizza spewed academic papers and Ph.D. theses like a geyser, says Turner. "One postdoc suggested a three-day 'cooling off' session before writing up a paper from Primordial Pizza," says Kolb with a laugh.

"All the big ideas in cosmology grew out of that period in the 1980s — cold dark matter, inflation, Big Bang nucleosynthesis," says Turner. "Back then, those ideas were avant-garde. Yesterday's revolution has become today's orthodoxy."

Schramm enthusiastically described the work of Turner and Kolb to his colleagues. He also urged his understudies to keep their most radical ideas to themselves until they could be tested with telescopic observations. "Sometimes we'd follow his advice and sometimes not," says Turner. It was all part of something Turner and Kolb dubbed "Schramm's razor" — set priorities, whenever possible, to focus on ideas that were "testable" with specific astronomical observations.

Ironically, the success of cosmologists in the 1980s doomed Warrenville. As the mysteries of cosmology yielded to more powerful telescopes and satellite experiments, Primordial Pizza lost its edge. It didn't survive the 1980s. "We were less tied down with data back then," says Kolb. Adds Turner, "Now, we have a more mature operation. It's less exciting. Some of the postdocs who ran to get the pizza are now full professors at universities."

Edward W. Kolb (standing) and Michael Turner Lloyd deGrane, Univ. of Chicago

Rex Graham is an Astronomy *senior editor.*

THE 8
GREATEST MYSTERIES
OF COSMOLOGY

Startling discoveries of the past century have revealed much about our cosmic origin, but huge mysteries remain.

by Mark Sincell

It's easy to forget that an astronomer discovered the first asteroid 200 years ago. Only 100 years ago, no one had seen Pluto, and astronomers believed the universe was contained in the starry confines of the Milky Way Galaxy. This picture has become vastly more complex as the 21st century begins.

Albert Einstein's General Theory of Relativity, which describes how gravity causes space-time to be curved, set the stage for theory to triumph over what appeared to be common sense, even his own. Although Einstein's theory predicted that every massive object puts a slight dent in the fabric of space-time, like a bowling ball on a mattress, the inventor of that superlative theory believed that the universe was unchanging. To keep it that way in his formulas, he postulated a new mathematical constant — the cosmological constant — to represent a repulsive force to keep the universe from collapsing under the influence of its own gravity.

An obscure Russian mathematician, Alexander Friedmann, realized that Einstein's ideas about gravity had another unforeseen solution — the universe could expand.

Subaru Telescope, NAOJ

The expanding-universe hypothesis also took shape in the mind of Belgian cosmologist and Catholic priest Georges Lemaître. In 1927, he argued that the well-known Doppler shift in light coming from "nebulae" (galaxies) to longer, redder wavelengths — indicating that the nebulae were moving away from Earth — showed that the universe is expanding. Lemaître theorized that the universe started out very small and expanded enormously. Of course, Einstein didn't buy it.

However, in the 1920s, the American astronomer Edwin Hubble used the brightnesses of variable stars to establish a distance scale to the galaxies. Hubble found that the farther away a galaxy was from Earth, the faster it was moving away from us. The expansion actually is an expansion of space, not the motion of galaxies across space, a concept that Hubble never fully accepted.

In 1948, Ralph Alpher and George Gamow built upon Hubble's observations and Lemaître's idea, and published a description of the Big Bang theory. It predicted a primordial state of incredibly hot matter consisting of neutrons and their decay products. The then-outlandish idea also included a testable prediction that was ignored for years: The cool relic of the Big Bang would be detectable on Earth as microwave radiation.

In 1964 and 1965, AT&T Bell Laboratories scientists Arno Penzias and Robert Wilson used a radio telescope that had been developed to listen to the first communication satellite to detect a ubiquitous microwave hiss. The noise was independent of the direction in which they pointed the antenna. They recalibrated and cleaned the telescope, but the signal persisted. The radio static remained the same whether Penzias and Wilson pointed their telescope in the direction of the sun or the Milky Way Galaxy, which suggested that the radiation was neither solar nor galactic in origin.

Penzias and Wilson soon realized the static was the microwave radiation predicted by Alpher and Gamow. Suddenly, the Big Bang wasn't so unthinkable. However, in the way of all great theories of the past centuries, the Big Bang raised more questions than it answered.

Three years ago, independent teams of astronomers led by Brian Schmidt of the Mount Stromlo and Siding Spring Observatories in Weston Creek, Australia, and Saul Perlmutter at the Lawrence Berkeley National Laboratory in Berkeley, California, were recording the brightnesses of distant supernovae, ostensibly to measure the deceleration of the expansion of the universe. Both teams found something every bit as unexpected as Penzias and Wilson's cosmic microwave background: The distant galaxies containing the supernovae aren't moving away from Earth at speeds that slow with time. Instead, the galaxies are accelerating away from us.

The structure of the universe is yielding to ever more powerful telescopes. In recognition of the way that knowledge generates even more questions, the following mysteries recognize the accomplishments of the past century and the work that lies ahead.

1 How multidimensional is the universe?

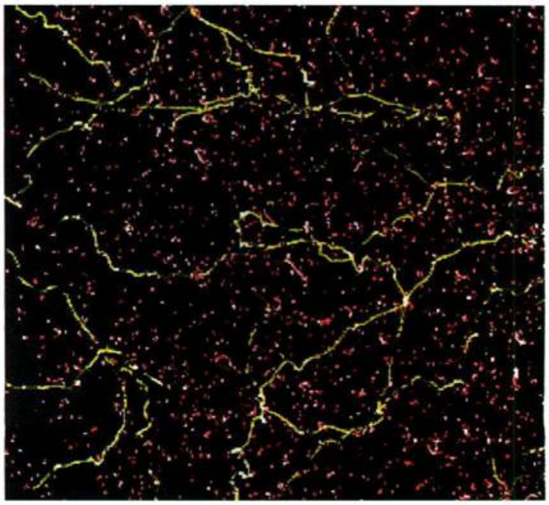
Except in magic shows, nobody can actually pull a rabbit out of an empty hat. For example, we live in a three-dimensional world, right? Perhaps not. Physicists have described the universe using four dimensions: the familiar three spatial dimensions and a time dimension. The model helped explain everything from the bending of starlight as it skirts the sun to the formation of black holes. Now, physicists think they may have to add several more spatial dimensions.

They are motivated by the "hierarchy problem." Simply put, they don't understand why gravity is vastly weaker than the other three fundamental forces of nature: the electromagnetic, strong, and weak forces. Physicists Lisa Randall of the Massachusetts Institute of Technology (MIT) in Cambridge, and Raman Sundrum of Johns Hopkins University in Baltimore, Maryland, recently proposed an explanation: add a dimension. In their model, we live in a four-dimensional world, but graviton particles, which carry the gravitational force, live in another. A small fifth-dimensional separation between the two worlds greatly diminishes the force of gravity.

String theorists go even further. They unify the four fundamental forces of physics in an 11-dimensional model in which tiny loops of "string" are the most fundamental particles. But even the most optimistic string theorists doubt they will see these strings anytime soon. Theory predicts that the strings are one hundred million billion times smaller than the smallest subatomic particle created in the most powerful particle accelerators.

Evidence for the fifth dimension could arrive much sooner. Randall and Sundrum predict that the Large Hadron Collider in Geneva, Switzerland, could generate enough energy to let a graviton briefly "leak" into our world.

Cosmic strings, like these generated by a computer simulation, could reign in an 11-dimensional universe.



C. B. Allen and E. P. Shellard

2 How did the universe begin?

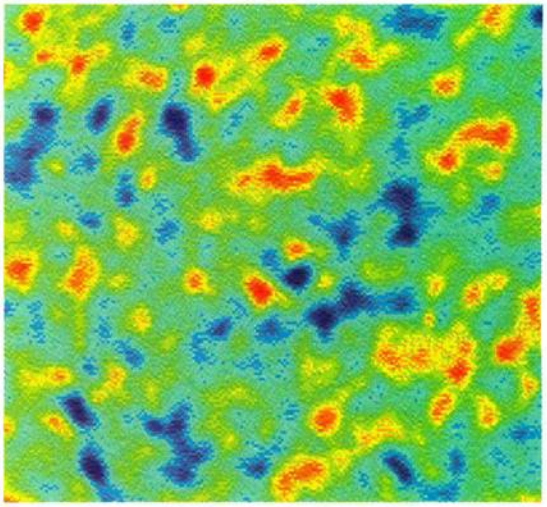
The consensus among cosmologists is that the visible universe erupted out of a singular event between 10 and 14 billion years ago. Within the first microsecond, the universe was an unimaginably hot soup of quarks and other exotic particles. As the soup cooled, quarks condensed into protons and neutrons, and their cousins, hadrons and mesons. By the time the universe reached the ripe old age of 1 second, only neutrons, protons, photons, electrons, and neutrinos (three types of lightweight elementary particles, and their antiparticle counterparts) remained. A series of nuclear reactions over the next 200 seconds created the nuclei of the three smallest elements.

Sound waves from the fading echo of the Big Bang rippled through the incredibly hot and dense fluid of the infant universe like the ripples left behind by a stone thrown in a lake. Pulled by the positively charged protons, a dense swarm of negatively charged free electrons accompanied the ebb and flow of the soup. Collisions with these electrically charged species corralled and herded the photons along. When the universe reached its 300,000-year birthday, however, it had cooled enough for atoms to form. The universe was suddenly transparent, which set the photons free. The liberated photons then carried the fossil imprints of the early density and temperature fluctuations as a pattern of brightness variations. Astronomers call this relic radiation, which was first detected by Penzias and Wilson, the cosmic microwave background (CMB).

When astronomers point microwave telescopes like the Cosmic Background Explorer (COBE) or the Balloon Observations of Millimetric Extragalactic Radiation and Geophysics (BOOMERANG) detector in one direction and measure the temperature of the CMB they observe radiation at 2.7° Celsius above absolute zero (2.7 Kelvins). When they look in the opposite direction, they again get 2.7 K. There are some fluctuations, but they are tiny. The largest variation in the CMB is one part in 100,000.

Cosmologists are intrigued by any explosion that could have generated such smoothness. It's as if turbulence — irregular motions that lead to hot and cold regions — didn't have a chance to operate. It is as if every part of the early universe was connected. How could that be possible? While puzzling over this problem in the late 1970s, physicist Alan Guth, then at Stanford University in Palo Alto, California, had a "eureka" moment. What if the visible universe started out as a tiny, extraordinary uniform bubble that suddenly expanded so fast that there was no time for it to change? Not only did Guth's inflation theory explain the one-part-in-100,00 smoothness of the CMB, but it also postulated that the lumpiness itself arose from quantum fluctuations occurring during inflation.

Cosmologists agree that, although the details are yet to be fully resolved, the tiny fluctuations in the early universe were amplified by gravity into the large lumps astronomers see today — galaxies, clusters of galaxies and other large-scale structures in the universe.



The Big Bang's aftermath contained tiny temperature variations that evolved into galaxy clusters and superclusters.

The Boomerang Collaboration

And Guth's inflation theory even made a testable prediction: an inflated bubble universe would appear "flat" in cosmological terms. Flat means that parallel lines will never cross, even if they travel across the entire universe.

In the past year, astronomers have repeatedly tested the prediction of Guth, now at MIT, by measuring the angular sizes of the tiny variations in the CMB. Every time, they find that the universe is flat. "It is the dumbest, simplest solution to Einstein's equations that you could write down," says Harvard University astrophysicist Martin White. "But it happens to describe the universe very accurately."

What drove inflation? Nobody knows. Physicists have suggested different models to describe the inflating universe, but all the solutions are mathematical conveniences with no particular physical basis. "All the theories of inflation amount to proof that we don't have one good theory yet," says Fermi National Accelerator Laboratory astrophysicist Edward W. "Rocky" Kolb.

3 Why does matter fill the universe?

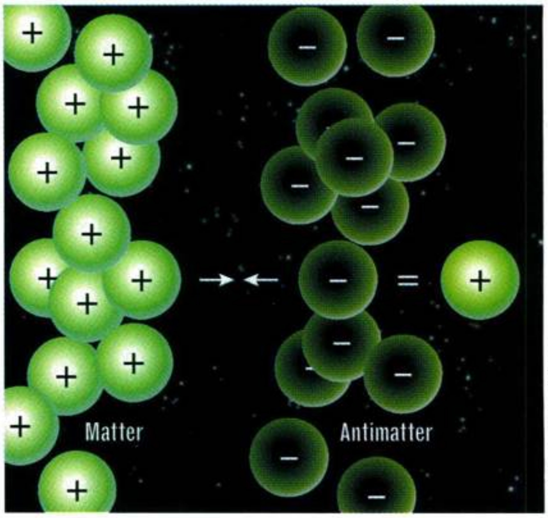
If the universe is exactly symmetrical, no planets, particles or people would exist because it would have contained equal numbers of particles and antiparticles. And particles and antiparticles quickly annihilate, producing gamma rays. Such a universe would be full of radiation and no atoms; however, virtually no antimatter exists in the universe, which is hard for theorists to explain.

Guth's inflation should have created equal amounts of matter and antimatter. (Of course, if matter and antimatter had formed in equal amounts and annihilated, there would be no theorists.) So how did matter survive annihilation?

It is possible that the antimatter did survive, but it somehow resides in a distant part of the universe that is too far away to see. "It could be that there are anti-galaxies with anti-people somewhere else," notes MIT physicist Jonathan Feng. "But that would have some strange consequences, which have not yet been seen."

A second possibility is that the universe is precisely symmetric, but it avoided the "annihilation catastrophe" after the Big Bang because the laws of physics have a slight preference for matter. This condition would have created a slight excess of matter, and the universe visible today is made of these leftovers.

In the mid 1960s, American particle physicists James Cronin and Val Fitch showed in their experiments that about 0.2 percent of the decay events of certain elementary particles violate the expected symmetry. Their colleagues were astonished. Cosmologists immediately argued that the results might explain why the universe has matter, but the case is far from closed.



Astronomy: Elisabeth Rowan

Matter and antimatter produced in the first moments of the universe would annihilate quickly, but the universe has a huge excess of matter and almost no antimatter.

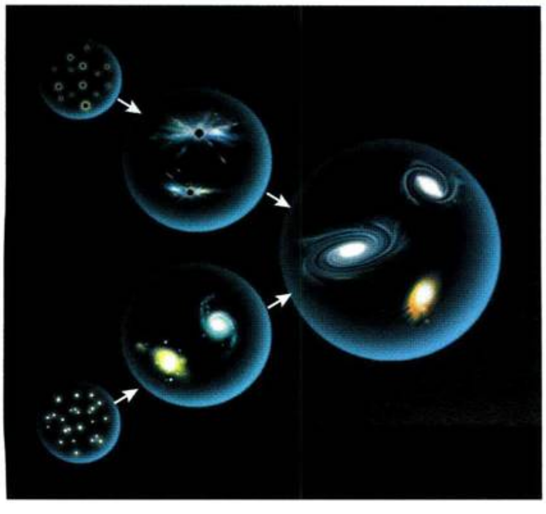
4 How did galaxies form?

"We have a cartoon description of galaxy formation that makes a vague kind of sense," says White, "but it is not concrete." Where did the lumpiness in the infant universe come from, and how were the lumps later amplified by gravity into galaxies?

Cosmologists can't answer those questions, but they agree that clumps of matter scattered through the young universe collapsed under their own gravity, dragging protons and neutrons (collectively called baryons) along and heating them. The fast-moving baryons collided, lost energy, stuck together, and sank into gravitational wells. Newborn galaxies strung themselves along the threads that wind over the surfaces of nearly empty light-year-sized voids.

Although three-dimensional galaxy maps generally confirm this bubble-bath model of the universe, the details are devilishly difficult to understand. Do colliding spiral galaxies produce elliptical galaxies? If the answer is yes, then why do the chains of elliptical galaxies and spirals seem to trace out different patterns in the foam?

Progress on these questions is slow, largely because it takes so long to measure galaxy distances. But it is steady, too. The Anglo-Australian 2dF Galaxy Redshift Survey has already collected 100,000 of the projected 250,000 galaxy distances, and the Sloan Digital Sky Survey expects to create a 3-D map of a million galaxies. After one year of operation, the Sloan team has measured the distances to about 60,000 galaxies. "These data will really help us crack open the question of galaxy formation," says Ohio State University astrophysicist David Weinberg.



Galaxy-mapping surveys may soon reveal which galaxy-formation model is correct.

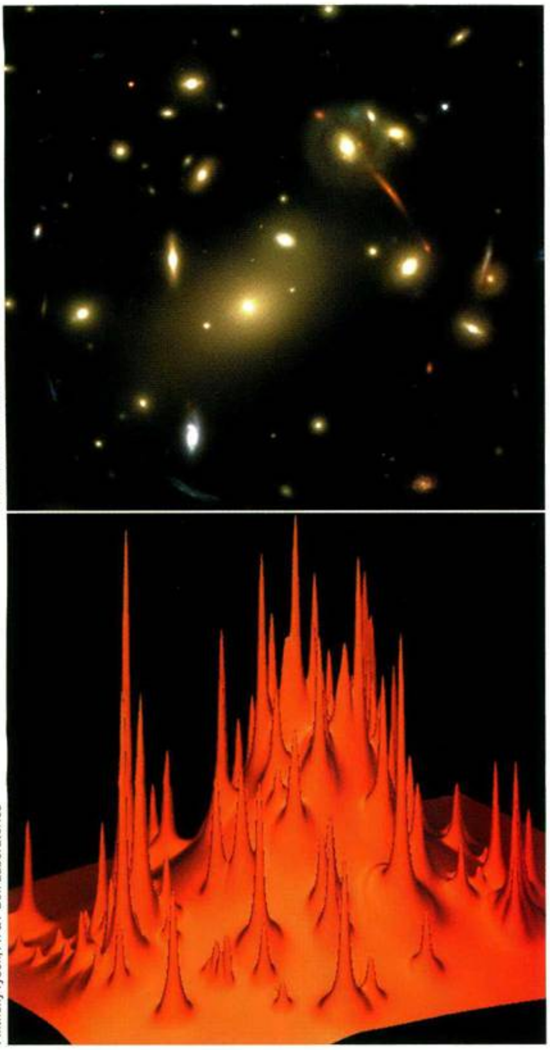
Astronomy: Elisabeth Rowan

5 What is cold dark matter?

All the stars and galaxies in the sky amount to roughly 0.5 percent of all the mass in the universe. And even if you add invisible clouds of atoms predicted to be floating in the distant universe the total only comes to 5 percent. The rest is cold dark matter and dark energy. Although astronomers can't see this dark matter directly, they know it accounts for about 30 percent of matter in the universe because of the way it pulls on stars and bends light. Cold dark matter is congealed into filaments that thread the surfaces of cosmic voids hundreds to millions of light-years across. This shape suggests that dark matter is slow-moving, therefore cold. Fast-moving "hot dark matter" would have long ago smeared out the universe's mass, preventing galaxy formation. And cold dark matter particles must interact very weakly, if at all, with normal matter; otherwise, the spherical dark-matter halos that surround the Milky Way and other galaxies would have flattened into galaxy-like pancake shapes.

If cold dark matter particles would only interact with normal material, they would be easy to find. Actually, they may do just that, but too weakly to reveal themselves. It takes longer than the age of the universe for most of these particles to have their first collision.

Physicists are trying two approaches to increase their odds of bumping into one of the



NASA, A. Fruchter, and the ERO Team

Anthony Tyson, AT&T Bell Laboratories

Top: Galaxy cluster Abell 2218. Bottom: Its "lensing" effect on a background galaxy reveals hidden dark matter.

unobtrusive particles. One idea is to go big. Annihilations of dark-matter particles and their antiparticles in the center of the Milky Way or in the core of the sun should create neutrinos. While neutrinos interact weakly with matter, one of these elementary particles should occasionally strike a water molecule, releasing a flash of light. In hopes of spotting one of these telltale flashes, physicists are converting the Mediterranean and Adriatic Seas and the South Polar ice cap into vast neutrino observatories by submerging long strands of light-sensing tubes in the water and ice.

Another idea is to go small, but accurate. Crystal-germanium in the Cryogenic Dark Matter Search (CDMS) detectors being built at Stanford University can ignore every known particle bouncing off the lattice. Now they are listening for the off-key ping of dark matter in a room 10 meters underground.

Some say the Italian Dark Matter Experiment (DAMA) team has found dark matter. It reported a seasonal signal from an underground detector that could be produced by Earth orbiting through a background of dark-matter particles. But other experiments haven't found such evidence.

Another dark-matter candidate is the axion, a diminutive particle that interacts so weakly with normal matter that experiments in the United States, Germany, and Japan haven't detected it.

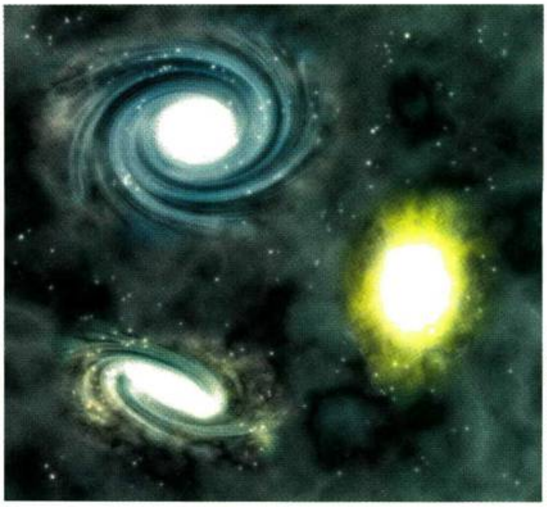
6 Are all the baryons assembled in galaxies?

Only 10 percent of the normal matter in the universe — baryonic matter made of protons, neutrons, and electrons — is in stars. Astronomers are trying to find more baryons with quasars, brilliant objects at great distances from Earth that are powered by black holes. If quasar light passes through baryons on its way to Earth, the atoms in the gas would leave their imprint on the quasar spectrum as absorption lines. But astrophysicists have found a tiny fraction of what they expect. Where have all the baryons gone?

Nowhere, say most astrophysicists: It is still floating in space. But in the billions of years since they formed, the clouds would have collided with each other, launching shock waves that heat the gas to around a million degrees Celsius. "It is an unfortunate coincidence," says Princeton University astrophysicist Jerry Ostriker, "but gas in that temperature range doesn't emit or absorb radiation strongly." Which means astronomers can't easily detect it. However, astronomers using the Hubble Space Telescope last year reported finding telltale hints of vast quantities of hydrogen between galaxies.

Computer simulations by Ostriker and Renyue Cen show that hot intergalactic gas should collect near galactic filaments. Later this year, Weinberg and his collaborators hope to spot x-ray emissions from the gas while using the Chandra X-ray Observatory for nearly six days to search for this elusive gas. "This is a lot of time to devote to a single observation that might detect nothing," says Weinberg. "It demonstrates the importance in finding this material."

The vast gaps between galaxies may not be empty. Astronomers using the Chandra X-ray Observatory will look for "missing" gas in them.



Astronomy: Elisabeth Rowan

7 What is the dark energy?

To get enough oomph to drive the present acceleration of the universe, dark energy must make up about 65 percent of the total density of the universe. The biggest problem with this idea is that no one has any idea what dark energy is. "So far, all we've been able to do is name it," says Turner. "It could be the energy associated with nothing, or the influence of hidden spatial dimensions."

At least astronomers know what it does. "It is repulsive like antigravity," says Perlmutter. "But it is not a force in the sense that it doesn't depend on the properties of the particles themselves. It acts directly on space." This new springiness of space is a bit like the inflationary expansion of the infant universe, except that dark energy is much slower to exert its effect.

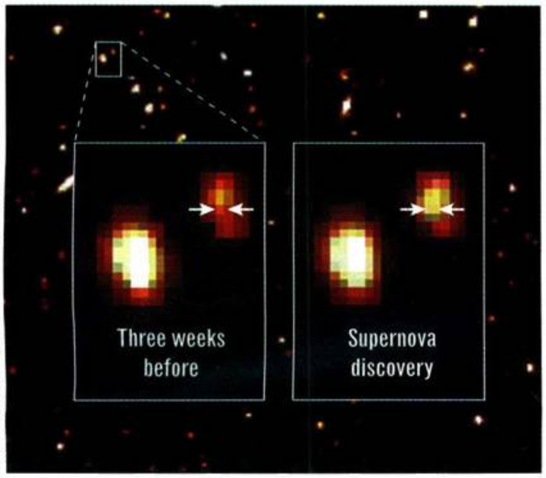
Physicists have tried to calculate the observed dark-energy density from accepted theories of physics, but their results don't jibe with reality. So far, the computed value is roughly 10^{60} times greater than the observed value. (Others say the number could be off by a factor of up to 10^{120}, but let's not quibble over the details.) Cosmologists are used to dealing in large numbers, but even they are worried about all the zeros. "There is something fundamental missing from our theories," says Kolb.

8 What is the destiny of the universe?

Most of the matter and energy in the universe resists expansion. If it had its way, the gravitational force of this material would eventually collapse the entire universe into a point. But dark energy makes the universe grow. Indeed, the fate of the universe is unknown because our understanding of dark energy is sketchy.

Dark energy is responsible for the current acceleration of the universe's expansion. And if the density of dark energy is a universal constant, or at least remains positive throughout the universe, then dark energy wins. The universe will continue to expand at a steadily increasing rate so that in 100 billion years we would only be able to see a handful of galaxies with today's telescopes.

Distant supernovae, used as "standard candles" to measure intergalactic distances, gave astronomers evidence that the expansion of the universe is accelerating.



Saul Perlmutter, Supernova Cosmology Project

James Hervat

If the expansion of the universe continues, as most cosmologists now believe it will, space will become a cold, lonely place tens of billions of years from now.

But dark energy — Einstein's famous cosmological constant — might actually be variable. It is even conceivable that it could become negative, which would make the universe collapse. "Even a change to a small negative value of the cosmological constant could make the whole universe recollapse," says Cambridge University astrophysicist Martin Rees.

At the moment, no telescope can see far enough to reveal which possibility is closer to the truth. In cosmological terms, the most distant supernovae that have so far been used to probe the density of the mysterious dark energy are our next-door neighbors. The scientists who will use the proposed SuperNova/Acceleration Probe (SNAP) satellite hope to remedy that technical problem. Orbiting far above the obscuring atmosphere of Earth, the dedicated supernova-hunting telescope will push the dark-energy frontier at least halfway back to the Big Bang to possibly settle this ultimate cosmological question once and for all.

The deep end of cosmology

These eight mysteries of modern cosmology are the ones that are just deep enough to perplex cosmologists without being so deep as to appear unanswerable. And if good fortune continues to smile on cosmology as it has in the past century, many scientists are optimistic that these questions may be answered by 2010. Does that prognosis mean cosmology is a problem on the verge of being solved? Unfortunately, no. Cosmologists can be certain of one thing: every answer generates other questions.

Astrophysicist and regular Astronomy *contributor Mark Sincell lives in Houston, Texas.*

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The 11" **Celestron NexStar 11 GPS** uses a built-in electronic compass and GPS (Global Positioning System) to tell this computerized go-to scope where it is on the earth in time and space, align it on the sky, and start finding over 50,000 deep sky objects for you . . . *automatically!* You don't have to level the tube, point it north, enter your latitude and longitude or the name of the nearest big city, calculate and enter universal time, compensate for daylight savings time, and do all the other little things that some go-to scopes need to have done for *them* before they can find deep space wonders for *you.* All you have to do is turn it on. The NexStar 11 GPS does the rest.

See our website for full details on this amazing telescope.

$2999

New lower prices on big SBIG CCD cameras!

SBIG has just brought out four new versions of the **ST-8E** 1534 x 1020 pixel enhanced blue sensitivity *self-guiding* two-chip imager (shown above). They've reduced prices on the ST-8E and ST-7E as well!

You can choose from three levels of chip cosmetics with the ST-8E, depending on your budget and imaging needs. Each chip level is available either with or without antiblooming, as you prefer. For spectroscopy, photometry, and critical imaging applications, Class 1 chips have no column or point defects.

The Class 2 versions have no column defects and a very limited number of point and cluster defects. This spec is actually an upgrade of the former ST-8E, at a price that's $1355 lower than the previous models! The Class 2 versions are designed for most scientific applications and excellent imaging.

The entry level Class 3 chip allows for some column, point, and cluster defects, but these can be eliminated by software for very good astronomical imaging at a price that's $1500 below competitive cameras with a similar size chip (although at the expense of restricted scientific applications).

We stock almost all available models of the Apogee LISÄÄ, Meade Pictor, and SBIG CCD cameras, self-guiding cameras, and autoguiders. We also carry a wide range of CCD accessories, as well – flip mirror systems, off-axis guiders, color filter wheels, image processing software, and more. Our large inventory means that the chances are good you won't have to wait to get the camera or accessory of your choice. Here are the SBIG cameras we normally keep in stock and their prices.

SBIG ST-5C track/accumulate camera	895^{00}
SBIG ST-237 track/accumulate camera	1195^{00}
SBIG ST-7E self-guiding camera	2650^{00}
SBIG ST-8E self-guiding camera, Class 1	7350^{00}
SBIG ST-8E self-guiding camera, Class 2	5995^{00}
SBIG ST-8E self-guiding camera, Class 3	4995^{00}
SBIG ST-9E self-guiding camera	3950^{00}
SBIG ST-10E self-guiding camera	7695^{00}
SBIG STV digital video camera/guider	1595^{00}
SBIG STVD digital video w/LCD screen	1995^{00}

TeleVue? We keep it in stock . . . including all the new optical tube configurations!

TeleVue TV-85, in stock

Hardly a week goes by that TeleVue doesn't send us warranty cards filled with glowing comments written by our customers about the TeleVue scopes they bought from us. But you expect those kind of comments when you sell TeleVue . . . because great products deserve high praise.

TeleVue has added some new products to their scope line, such as optical tube versions of the **Pronto**, **Ranger**, and **TV-85.** These models come without eyepiece or diagonal, allowing you to benefit by upgrading to superb TeleVue optics while using your existing eyepieces and star diagonal. There's also a new version of the **TV-102** optical tube that now includes a 2" Everbrite diagonal, tube ring, and eyepiece.

All TeleVue scopes are built to the same uncompromisingly high optical and mechanical standards. Their short focal lengths give you an observing flexibility many other scopes lack. Each has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power, all without losing optical quality (one test report said they used an amazing 89x per inch of aperture on the Ranger, TeleVue's least expensive model).

In addition to telescopes, we stock TeleVue eyepieces; Barlows; camera adapters; mounts; Starbeam and Qwik-Point finders, and all other accessories in depth. If it's a product that comes from TeleVue, the chances are good we have it in stock for immediate shipment.

TeleVue eyepieces, all models in stock

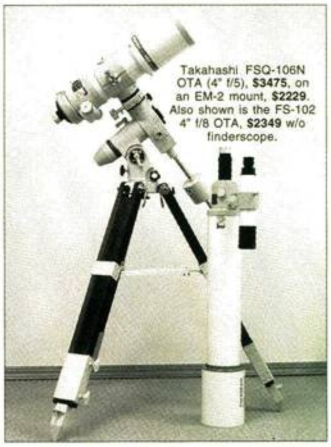
Takahashi – another name for premium optics.

While many people swear *at* the long delivery times quoted by some premium refractor manufacturers, most knowledgeable astronomers swear *by* the unsurpassed optical quality and fast delivery of the Takahashi apochromatic refractors we keep in stock.

From the 2.4" **FS-60C** OTA at $829 to the 6" **FS-152** OTA at $8999, we stock Takahashi fluorite apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast.*

Why wait for 1-3 *years* to get your apo refractor or mount from another manufacturer? You can be usually be viewing through a superb Takahashi apo only a few short days after you order from us. We can also special order larger scopes with 1-3 month delivery times.

We stock complete Takahashi scopes on mounts, as well as apochromatic optical tubes for use on your own mount.



Takahashi FSQ-106N OTA (4" f/5), **$3475**, on an EM-2 mount, **$2229**. Also shown is the FS-102 4" f/8 OTA, **$2349** w/o finderscope.

Takahashi FCL-90 ***Sky 90*** OTA (3.5" f/5.6), shown with dew shield retracted, **$2279**

A very hot Takahashi's is the unique **FCL-90** ***Sky 90*** 90mm f/5.6 refractor. With its self-storing dew shield retracted, as shown above, this remarkable telescope is less than 14" long! It makes a great traveller scope that you can stow away anywhere – *and it's available!*

We also stock the 22" long Takahashi **FSQ-106N** 4" 4-element f/5 dual fluorite astrograph apo refractor OTA. It's also a great travelling scope.

If you want premium optics, and you want them *now,* the first name you should think of is Takahashi. The second name should be . . . ***astronomics***.

Nine go-to computerized scopes you assemble in minutes!

$499

114GT

You won't spend hours assembling **Celestron NexStar** go-to scopes. They're preassembled. All you do is slip the scope base into the tripod, hand tighten one large knob, and you're ready to observe . . . with no tools needed! There are even four new **FirstStar** tabletop models that don't require assembly at all! Just put them on a table and start observing! The **NexStar 114GT**, left, is a 4.5" aperture f/9 reflector. The **NexStar 80GT**, right, is an 80mm f/5 refractor. All give you multiple eyepieces, a Star Pointer finder, dual motor drives, and a go-to computer to make astronomy easy. Prices start at only $199 for a 50mm tabletop, up to $599 for a 130mm (5.1") reflector and tripod. All are so sensationally easy to use that you'll be observing in minutes.

$399

80GT

A 4" computerized go-to Mak for $699!

The 4000+ object computer of the new **Celestron NexStar 4** Maksutov-Cassegrain is standard equipment, not an option as it is with some scopes. The computer hand control docks conveniently in the scope's sleek single fork arm mount. The battery-operated tabletop NexStar 4 is so easy to use that you'll be observing a short 10 minutes after you take it out of the box, even if you've never owned a telescope before.

$699

NS4

A free tripod with the NexStar 5 go-to SCT!

You'll now get a $149 retail NexStar adjustable height aluminum tripod and wedge for free when you buy a **Celestron NexStar 5** go-to 5" Schmidt-Cassegrain telescope. The $1199 scope hasn't changed in price, you're just getting a free bonus that's worth $149!

Finally . . . shake-free binocular observing!

"Truly a quantum leap in binocular observing," is what *Sky & Telescope* said about the Canon image-stabilized binoculars. They also said "astounding . . . supercrisp . . . particularly impressive was how well these binoculars compared to much larger apertures . . . " There's no shake, no blur, no jittery images while hand-holding these high power binos, just rock-solid astronomical observing. From 10 x 30mm to 18 x 50mm, Canon has an image-stabilized binocular that's right for you.

24-Hour FAX line: (405) 447-3337 Our e-mail address: questions@astronomics.com
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No credit card surcharge. $6.95 minimum freight. All returns less freight. Restocking fees apply to returns for credit and to merchandise returned used or damaged.

sky Show

june

Brilliant Mars dominates the southern sky.

by Martin Ratcliffe and Alister Ling

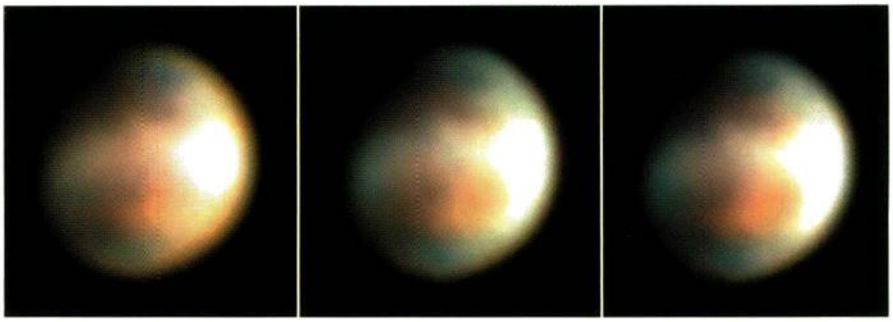
Observers all around our blue planet have been waiting more than two years to see Mars up close and personal. Instead of resembling a tiny ochre hazelnut, Mars swells to a wonderfully detailed 21" disk this month; that's practically half the apparent size of Jupiter. This means that under steady conditions you'll be able to see a wealth of surface features.

The last time Mars was this big and bright was when the sun, Earth and Mars lined up (called opposition), in 1988. If oppositions happen when Mars is at its far point from the sun, or aphelion, Mars can appear no bigger than 13". The next time we reach opposition, in August 2003, the Red Planet will appear 25" across, about as large as possible.

Check out how Mars surges in luminosity as we approach opposition on the 13th. At the end of April, it didn't hold a candle to Sirius setting in the southwest, but by mid-May it surpasses this bright star. During the next four weeks, to reach opposition, Mars blazes a full magnitude more. That's almost the difference between Vega and Deneb, two of the brilliant stars that make up the Summer Triangle.

Make sure you observe Mars on those oppressive, hot and humid nights, which tend to occur when Earth's atmosphere is calmest. Then details will stand out best.

The summer solstice marks the longest day of the year, if you live north of the equator. When the sun is due south near noon, it appears as high in the sky as possible. Completely opposite the sun lies the full moon on the 6th, right where the sun will be at the winter solstice. The path of the summer moon is that of the winter sun. We reach summer solstice on June 21, at 3:38 A.M. EDT. Later that day, a total eclipse of the sun sweeps across south central Africa.



Mars reveals more markings (here on February 8, 2001) as its size grows. Donald C. Parker

Venus, Jupiter, Mars, and the moon gather on June 15, 1991. James R. Foster and Michael Stecker

Because the dawn breaks so early in June, most people will miss Venus as the morning star. It won't return into the evening sky until 2002. Mercury is just finishing a lovely evening apparition. Catch it before it slips away, before May 25th, low in the west-northwestern sky about 50 minutes after sunset. Use binoculars to sweep just above the horizon.

Comet 24P/Schaumasse is swinging back into deeper space and fading. To see this "dirty snowball," drive out into the country after the 8th, when the moon is out of the evening sky. Take advantage of the darker sky to spy a host of globular clusters hovering around the core of our galaxy.

For many Canadians and Europeans, there is no total darkness in June. It's a good time to set your sights on brighter objects, like double and variable stars, as well as asteroids. Not far from Mars lies asteroid 14 Irene, which you can track down from a city backyard.

2001
June

4 Pluto is at opposition, 8 A.M. EDT (page 63)

5 Full moon is at 9:39 P.M. EDT

6 The moon passes 4° north of Mars, 3 P.M. EDT

7 Asteroid Isis is at opposition, 11 A.M. EDT

8 Venus is at greatest western elongation (46°), 1 A.M. EDT

10 The moon passes 3° south of Neptune, 4 A.M. EDT
Asteroid Irene is at opposition, 1 P.M. EDT (page 65)

11 The moon passes 3° south of Uranus, noon EDT
The moon is at apogee (251,425 miles from Earth), 3:48 P.M. EDT

13 Mars is at opposition, 2 P.M. EDT (page 62)
Last quarter moon is at 11:28 P.M. EDT

14 Jupiter is in conjunction with the sun, 9 A.M. EDT

16 Mercury is in inferior conjunction, 9 A.M. EDT

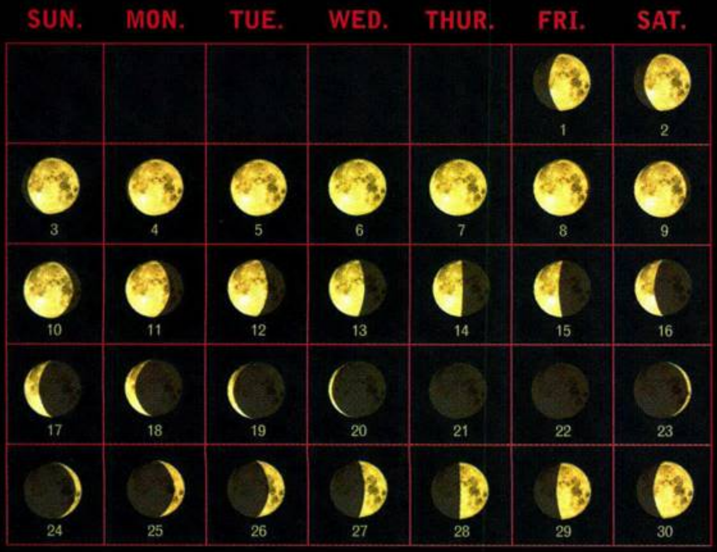
17 The moon passes 1.7° south of Venus, 6 P.M. EDT

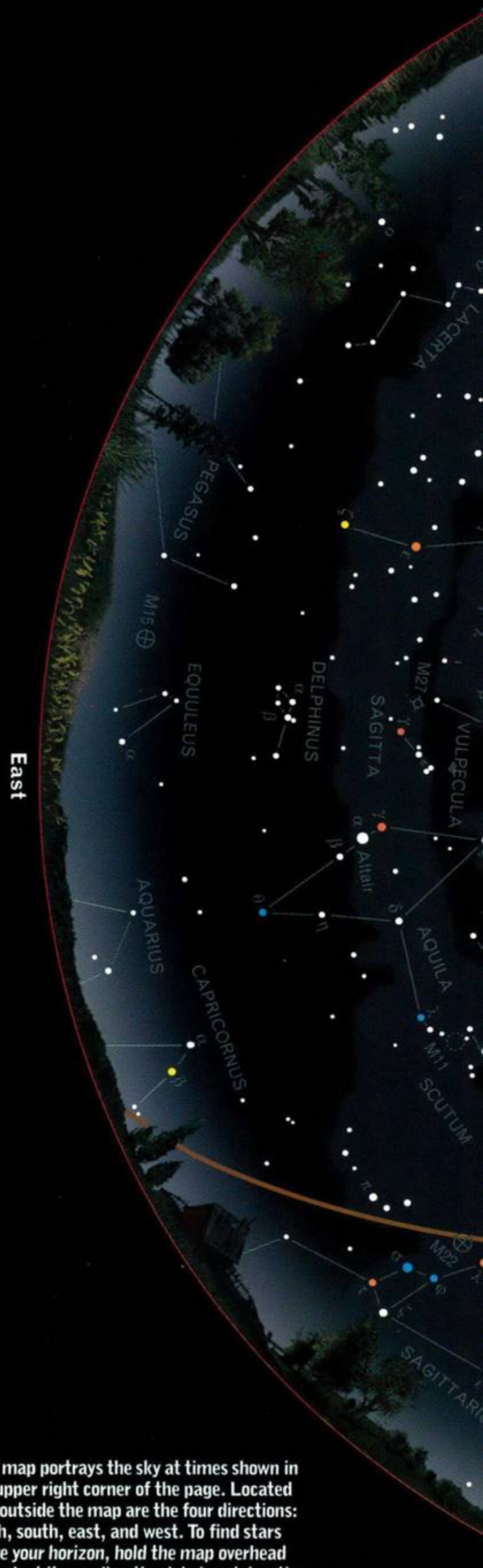
19 The moon passes 0.9° south of Saturn, 6 P.M. EDT

21 Summer solstice is at 3:38 A.M. EDT
New moon is at 7:58 A.M. EDT; total solar eclipse (page 64)
Mars is closest to Earth (41.8 million miles away), 7 P.M. EDT

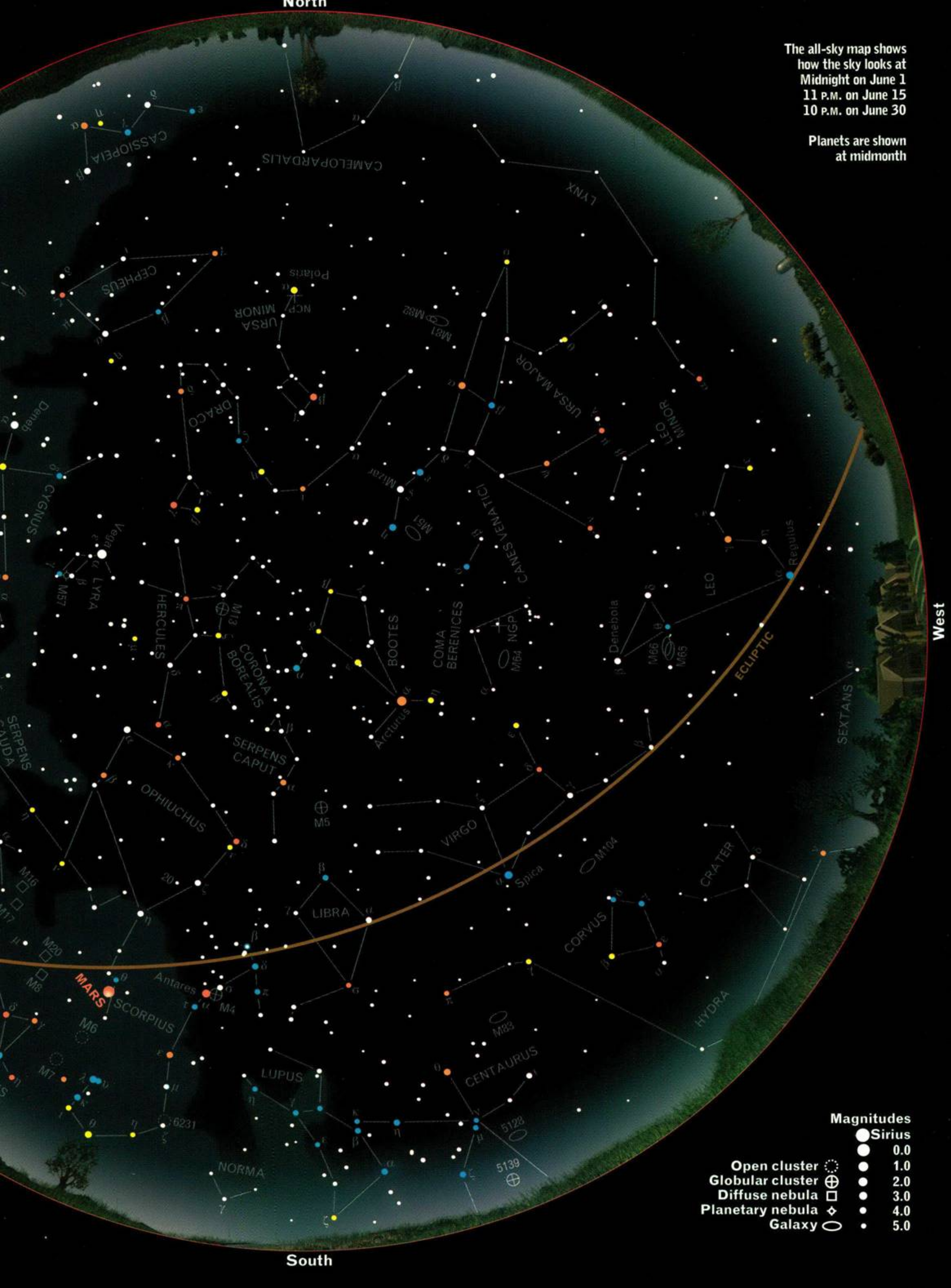
23 The moon is at perigee (225,640 miles from Earth), 1:19 P.M. EDT

27 First quarter moon is at 11:19 P.M. EDT





This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

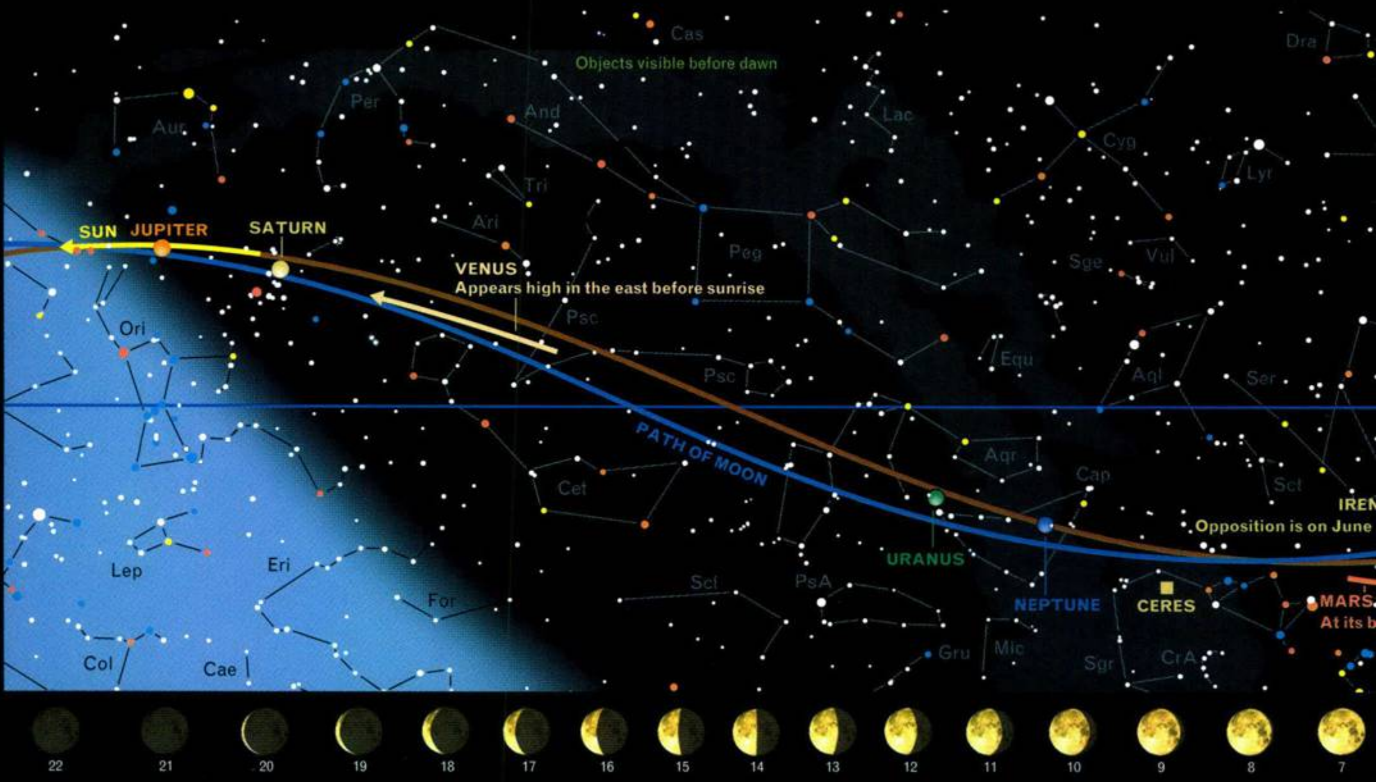

North
CASSIOPEIA
CAMELOPARDALIS
LYNX
CEPHEUS
Polaris
NCP
URSA MINOR
M81
M82
URSA MAJOR
LEO MINOR
DRACO
Deneb
CYGNUS
Mizar
M51
CANES VENATICI
Regulus
Vega
LYRA
M57
HERCULES
M13
BOOTES
COMA BERENICES
NGP
M64
Denebola
M66
M65
LEO
West
CORONA BOREALIS
Arcturus
SEXTANS
ECLIPTIC
SERPENS CAUDA
SERPENS CAPUT
OPHIUCHUS
M5
VIRGO
M104
CRATER
Spica
M16
M17
20
LIBRA
CORVUS
M20
M8
MARS
Antares
M4
SCORPIUS
M6
M83
HYDRA
M7
LUPUS
CENTAURUS
6231
5128
NORMA
5139
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
Midnight on June 1
11 P.M. on June 15
10 P.M. on June 30

Planets are shown
at midmonth

Path of the Planets

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects


Cas
Objects visible before dawn
Dra
Aur
Per
And
Lac
Cyg
Lyr
Tri
Ari
Peg
Sge
Vul
SUN
JUPITER
SATURN
VENUS
Appears high in the east before sunrise
Psc
Ori
Psc
Equ
Aql
Ser
PATH OF MOON
Aqr
Cap
Cet
Sct
IREN
Opposition is on June
URANUS
Lep
Eri
Scl
PsA
For
NEPTUNE
CERES
MARS
At its b
Gru
Mic
Sgr
CrA
Col
Cae
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21
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16
15
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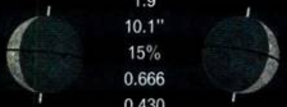
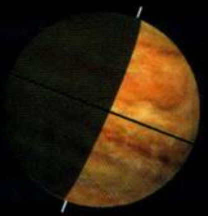
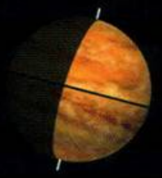
11
10
9
8
7

To locate the moon in the sky, draw a line from the phase shown for the day straig

PLANETS	MERCURY	MERCURY	VENUS	VENUS	M
Date	June 1	June 30	June 1	June 30	Ju
Magnitude	1.8	1.9	−4.4	−4.2	-
Angular Size	10.2''	10.1''	25.9''	19.1''	2
Illumination	16%	15%	45%	60%	1
Distance (AU) from Earth	0.660	0.666	0.643	0.875	0
Distance (AU) from Sun	0.445	0.430	0.728	0.728	1
Right Ascension (2000.0)	5h58.1m	5h23.7m	1h35.6m	3h28.8m	17h
Declination (2000.0)	23°59'	18°46'	7°43'	16°03'	−

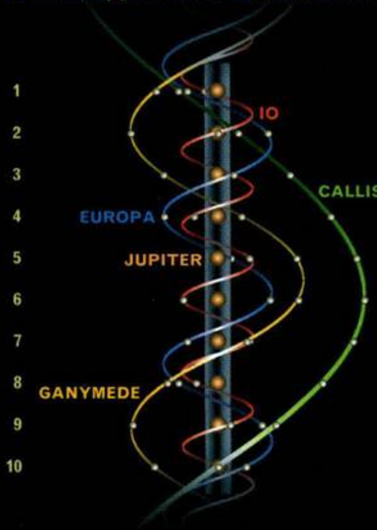


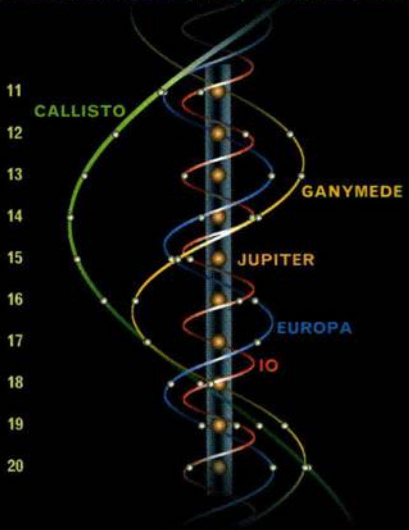


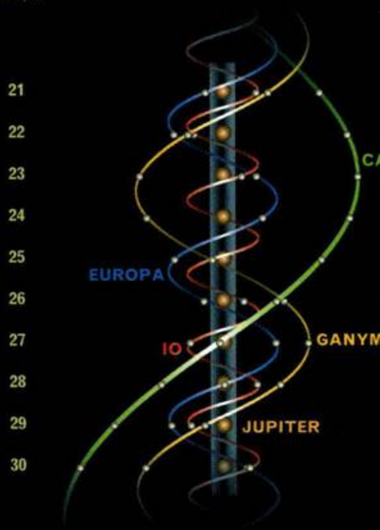


Jupiter's Moons

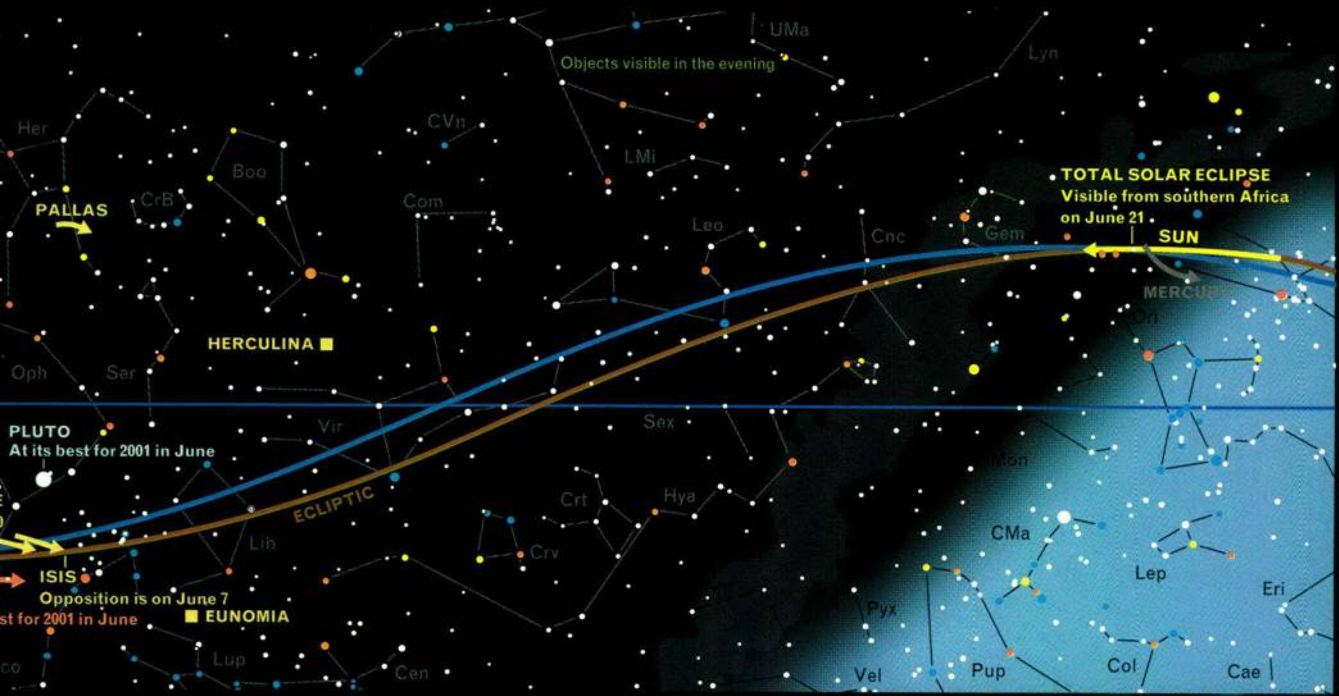
Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.

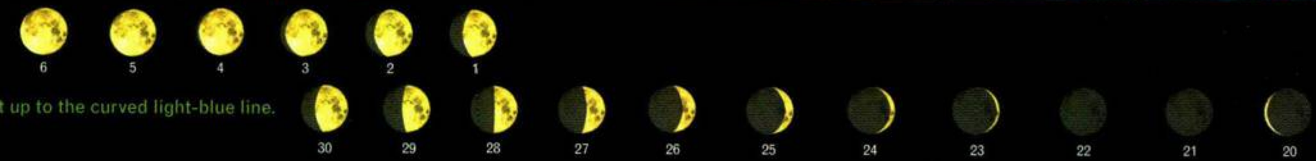






during the month.


UMa
Objects visible in the evening
Lyn
Her
CVn
LMi
Boo
PALLAS
CrB
Com
Leo
TOTAL SOLAR ECLIPSE
Visible from southern Africa
on June 21
Cnc
Gem
SUN
MERCU
Ori
HERCULINA
Oph
Ser
PLUTO
At its best for 2001 in June
Vir
Sex
Mon
ECLIPTIC
Crt
Hya
CMa
Lib
Crv
ISIS
Opposition is on June 7
st for 2001 in June
EUNOMIA
Lep
Eri
Pyx
co
Lup
Cen
Vel
Pup
Col
Cae


6
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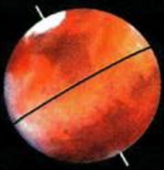
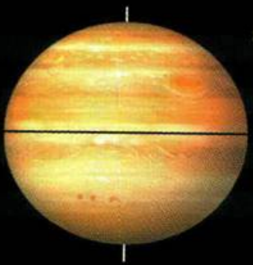
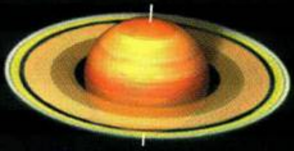
t up to the curved light-blue line.



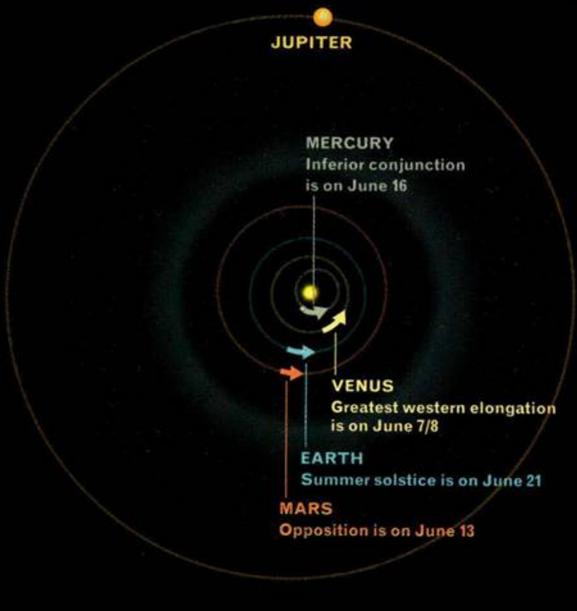




RS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
e 15	June 30	June 30	June 15	June 15	June 15
2.4	–1.9	0.1	5.8	7.9	13.8
.6"	32.3"	16.7"	3.6"	2.3"	0.1"
0%	100%	100%	100%	100%	100%
54	6.098	9.957	19.456	29.369	29.409
69	5.104	9.086	19.972	30.102	30.392
5.7m	5h47.2m	4h29.5m	21h49.0m	20h43.3m	16h54.2m
°33	23°07'	20°06'	–13°59'	–18°01'	–11°48'

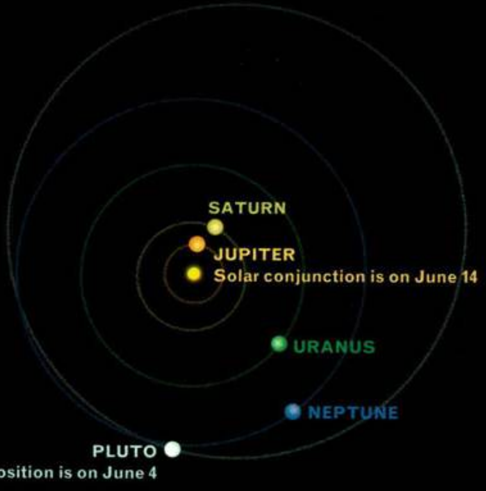
LISTO

DE


JUPITER
MERCURY
Inferior conjunction
is on June 16
VENUS
Greatest western elongation
is on June 7/8
EARTH
Summer solstice is on June 21
MARS
Opposition is on June 13

The Planets in Their Orbits

Arrows and dots show planets' positions during the month.


SATURN
JUPITER
Solar conjunction is on June 14
URANUS
NEPTUNE
PLUTO
Opposition is on June 4

Mars Highlights a Garden of Plenty

Luckily for us, the universe is filled with a remarkable variety of things to see. While you wait for Mars to climb higher in the southern sky, feast your eyes on the differences between double stars, globular star clusters, and a stellar remnant, all with just slight pointing adjustments to your telescope. Begin at Theta (θ) Ophiuchi, located one-third of the way from brilliant Mars (whose Greek name is Ares) to its eternal rival, ruddy Antares. Just 1° (two apparent moonwidths) northwest lies the attractive double star Omicron (ο) Ophiuchi. Bump up the power to 150x to notice that the yellowish magnitude 5.2 primary is accompanied by a pale blue 6.6 magnitude secondary almost due north.

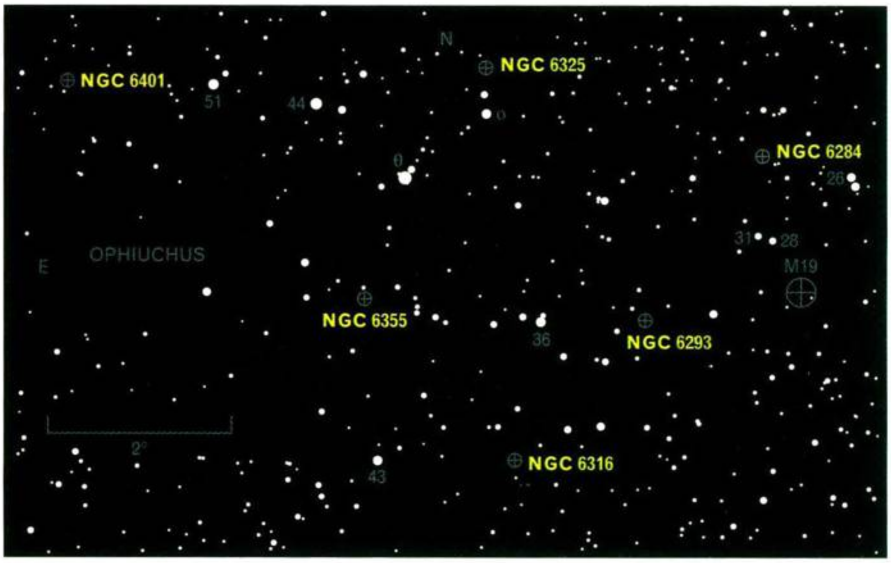
A little bit farther but southwest of Theta is another charming double star, 36 Ophiuchi. This is an almost identical pair of yellow-orange magnitude 5.1 stars, separated by 4.9" (about one quarter the apparent size of Mars). Diagonally opposite 36 Oph from Theta Oph is the "Little Ghost" planetary nebula, NGC 6369. It is a perfect ring-shaped gas cloud, about 30" across, about half the size of the more famous Ring Nebula, M57 in Lyra. They're called planetaries because they can appear like pale gas giant planets in a telescope. In reality they are the dying gasps coughed out near the end of a red giant's stellar life. You'll probably need an 8-inch scope to catch their translucent glow from urban areas.

If you have an equatorial scope, it will be a snap to locate two similar globular clusters, which are densely packed star clusters, from our anchor star Theta Oph. Messier 9 is 6.4° north, and Messier 19 is 4.4° west and just a tad south. M19 is the brighter and bigger of the two. They will both appear as unresolved fuzzballs unless you're under dark country skies with a scope 10 inches or bigger. Ophiuchus is home to many globular clusters. Although the globulars are arranged fairly evenly around our galaxy, our view from "far out" makes them appear to be bunched together in that part of the sky.

On a moonless night in the country, use the chart to hunt down these clusters. At low power you could mistake the fuzzy brighter globular core for a field star, so don't forget to notch the magnification up past 100x. NGC 6325, at magnitude 10.7, will be the most challenging, despite being only one moonwidth north of Omicron Oph.

Ophiuchus Globulars

NGC 6284	Mag 9.0
NGC 6293	9.2
NGC 6316	9.0
NGC 6325	10.7
NGC 6342	9.9
NGC 6355	9.6
NGC 6356	8.4
NGC 6401	9.5



The rich region of Rho Ophiuchi is home to many globular clusters. August R. Orlandi

Mars reaches opposition on June 21, and represents the best time since 1988 to view the Red Planet. It is also at its brightest in 13 years, shining at magnitude –2.4 on June 13. Medium-sized telescopes (8-inch and up) will show Mars well. Later we'll take a look at what can be seen throughout June.

Mars rises soon after sunset in the southeastern sky in the constellation of Ophiuchus. Observers without telescopes can follow its westward motion against the background stars. This retrograde motion takes Mars to within 8° of Antares, the famous "rival of Mars," now clearly less brilliant than its planetary neighbor. Mars stays above the horizon all night, and is best around local midnight when it is at its highest above the southern horizon. Look for Mars as it rises with the month's full moon on June 6. The two lie 5° apart.

Not every opposition is as good as this year's event. The elliptical orbit of the planet is such that Mars can come as close as 34.6 million miles or as distant as 61 million miles at opposition. This year's 42 million miles provides an apparent diameter of 21" for the planet. At its best opposition it reaches 25". It's considered a favorable opposition anytime Mars reaches over 20" as seen from Earth.

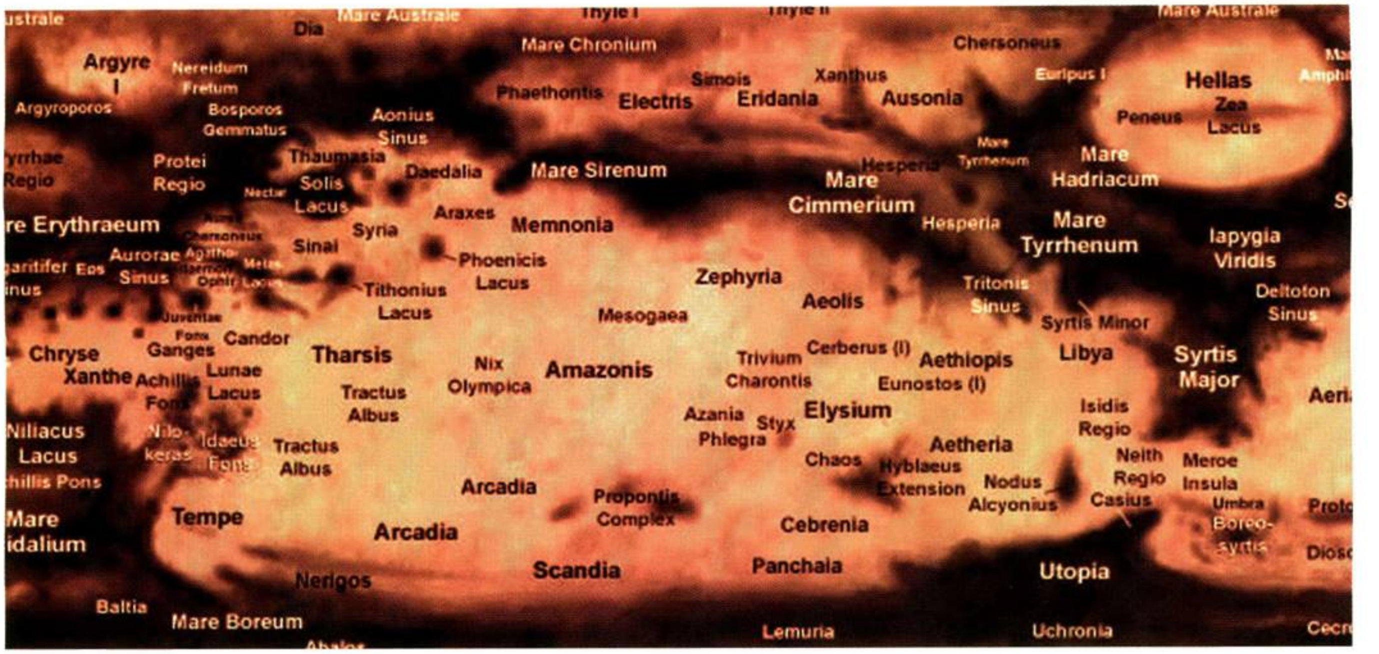
Central Meridian Longitudes on Mars

Principal Day	10 P.M.	Midnight	Features
May 31	330°	0°	Sinus Sabaeus
June 4	295°	325°	Syrtis Major
9	250°	280°	Hellas
14	206°	236°	Mare Cimmerium
19	162°	192°	
24	118°	148°	Mare Sirenum
29	73°	103°	Solis Lacus, Tharsis Desert

Mars will only be this size for a short time, however, so use every opportunity to get a good view. Even at 21", Mars appears smaller than the lunar crater Copernicus. Consequently, its disk is heavily affected by atmospheric seeing. Choose your viewing nights wisely, and remember that thermal currents inside your telescope tube will significantly affect seeing. Observers who take care to avoid these effects will obtain the best results. A really good view of Mars provides a lasting memory.

The opposition of Mars this month occurs at the same time as the autumnal equinox on the Red Planet, and so our view is directly at its equator. Both hemispheres on Mars are being warmed equally. Each polar cap lies on opposing edges of the martian disk. A line joining each pole and running centrally through the planet is called the central meridian. Since the longitude of features on Mars is well-determined, feature visibility can be predicted ahead of time in order to plan observations.

Mars rotates in 24 hours and 39 minutes; consequently, the same features will arrive at the central meridian 40 minutes later each night. Throughout a period of 36 days, the entire martian globe will parade before you. Soon after Mars rises, some of the best-known dark features are on display in early June. The following comments


ustrale
Dia
Mare Australe
Thyle I
Thyle II
Mare Chronium
Chersoneus
Mare Australe
Argyre I
Nereidum Fretum
Argyroporos
Bosporos Gemmatus
Aonius Sinus
Phaethontis
Electris
Simois
Xanthus
Eridania
Ausonia
Euripus I
Hellas
Zea Lacus
Peneus
yrrhae Regio
Protei Regio
Thaumasia
Nectar
Solis Lacus
Daedalia
Mare Sirenum
Hesperia
Mare Tyrrhenum
Mare Cimmerium
Mare Hadriacum
re Erythraeum
Aurorae Sinus
Chersoneus
Agathodaemon
Melas
Ophir
Sinai
Syria
Araxes
Memnonia
Hesperia
Mare Tyrrhenum
Iapygia Viridis
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Phoenicis Lacus
Tithonius Lacus
Zephyria
Aeolis
Tritonis Sinus
Deltoton Sinus
Juventae Fons
Candor
Ganges
Mesogaea
Syrtis Minor
Chryse
Xanthe
Achillis Fons
Lunae Lacus
Tharsis
Nix Olympica
Amazonis
Trivium Charontis
Cerberus (I)
Aethiopis
Eunostos (I)
Libya
Syrtis Major
Tractus Albus
Azania
Styx
Phlegra
Elysium
Isidis Regio
Aeri
Niliacus Lacus
hillis Pons
Nilokeras
Idaeus Fons
Tractus Albus
Chaos
Hyblaeus Extension
Aetheria
Nodus Alcyonius
Neith Regio
Casius
Meroe Insula
Umbra Boreo-Syrtis
Prot
Arcadia
Propontis Complex
Cebrenia
Mare idalium
Tempe
Arcadia
Scandia
Panchaia
Utopia
Dios
Nerigos
Baltia
Mare Boreum
Abalos
Lemuria
Uchronia
Cecr

As the Red Planet reaches opposition, many features will be visible in scopes. Dan Troiani refer to observing Mars before midnight. Different features will be on view for observations after midnight.

Sinus Sabaeus, a dark linear feature that runs into Meridiani Sinus, is near the central meridian during the first few days of June. The most prominent feature on Mars is Syrtis Major, a delta-shaped darkening visible in most telescopes. Syrtis Major is positioned almost centrally on the disk during evenings in the second week of June. In addition, the very bright region called the Hellas Basin is visible. This giant flat basin is often confused with one of the polar caps.

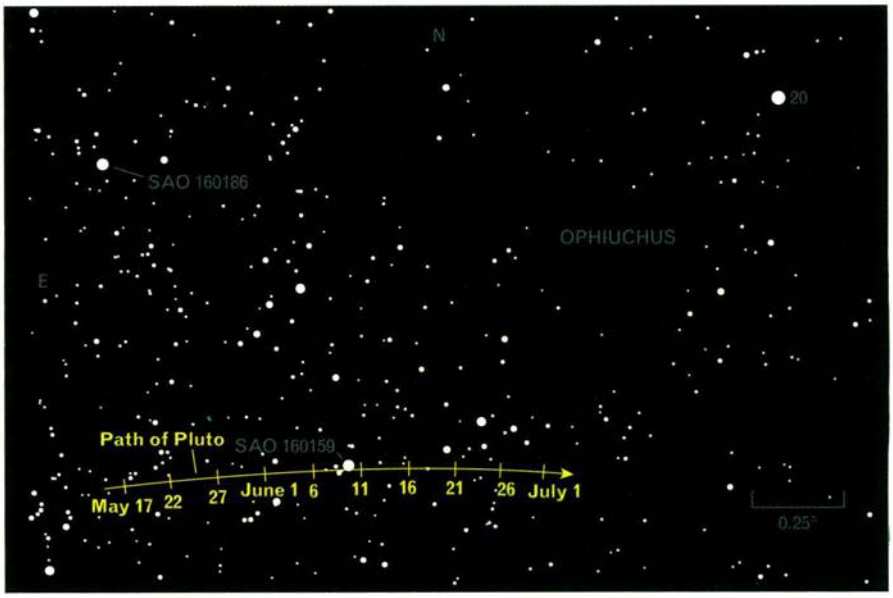
The region on Mars with the fewest of distinct features faces Earth during the evenings of the third week of June. The Tharsis desert and Arcadia have few strong features that can be seen through amateur telescopes. However, very large telescopes have a chance of detecting the dark, thin, linear mark representing the Valles Marineris, if perfect conditions prevail. Toward the end of June the dark feature Solis Lacus appears centrally on Mars. Mars is a challenging object to observe, but a good dose of patience will treat you to spectacular views.

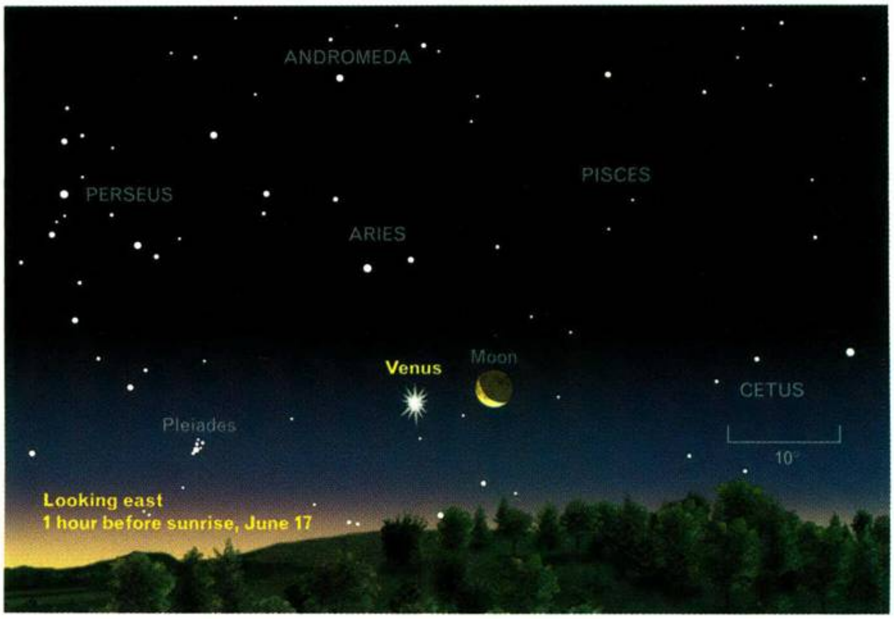
To the north of Mars and also in Ophiuchus is the faintest of all the nine planets, **Pluto**. Opposition for Pluto occurs on June 4, when it reaches magnitude 13.7. Tracking down Pluto among the crowded star field near the star 20 Ophiuchi is tricky, and is best done over a few nights. Carefully draw the same star field that contains Pluto night after night to reveal the wandering planet.

Now let's move to a pair of planets at the outer reaches of the solar system. **Uranus** and **Neptune** currently lie in Capricornus, the Sea Goat. Both lie above the southeastern horizon by 1 A.M. local time. Neptune reaches opposition next month, when it passes very close to the magnitude 5.3 star, Upsilon (υ) Capricorni. Watch it move from its current position of less than 1° east of the star. Neptune glows at magnitude 8.

Venus reaches greatest western elongation on June 8. It won't reach any great altitude above the horizon for Northern Hemisphere observers due to the low angle of the ecliptic with respect to the horizon during June mornings. Watch the eastern sky before dawn on June 17 for this month's most spectacular view of the planet. It rises more than two hours before the sun along with the Pleiades and a waning crescent moon 7° to its right. Venus glows at magnitude –4.5 and a telescopic view will reveal its "half-moon" phase. As it moves away from the sun the telescopic appearance of Venus reveals a waxing crescent.

Watch also for the reappearance of **Saturn** from behind the sun as it rises before dawn in the east-northeast. It stands 11° below the Pleiades and shines at magnitude 0.1. Saturn lies 6° to the left of the slender crescent moon on June 19. In late June, **Jupiter** reappears low in the east before sunrise, and is briefly joined by **Mercury**. Mercury begins the month as an evening "star," and passes through inferior conjunction on June 16. Each of these planets will be inconspicuous this month.





Looking east
1 hour before sunrise, June 17

Meteors and Moons

Total Eclipse

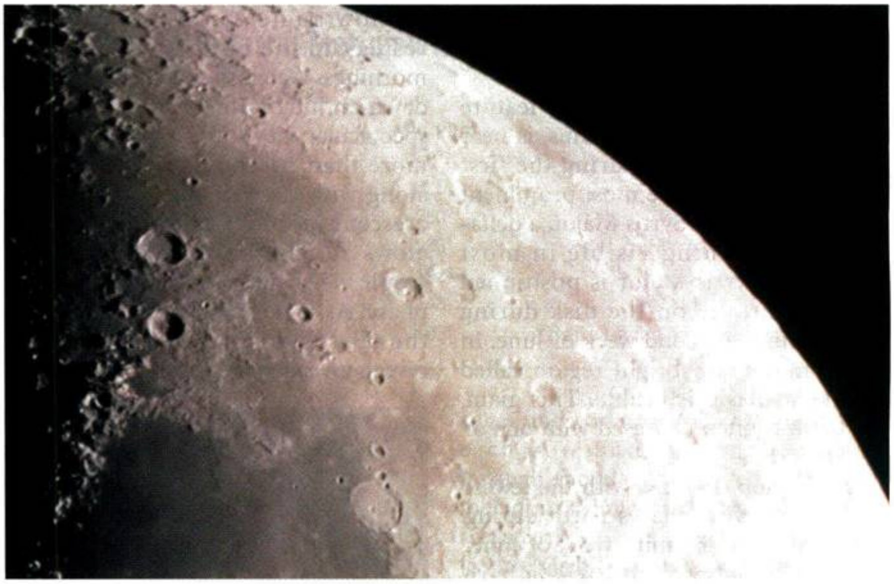
The moon fully eclipses the sun for observers located in southern Africa and Madagascar on the day of the summer solstice, June 21. As the sky darkens, Jupiter will be visible just 5° from the totally-eclipsed sun. The eclipse is the longest until 2009, lasting up to 4 minutes 55 seconds. No part of the eclipse is visible from North America.

Meteors

The June Boötids provided a flurry of activity in 1998 when the shower produced an unexpectedly strong rate of between 50 to 100 meteors per hour. Some astronomers suspect the shower is related to the periodic comet 7P/Pons-Winnecke that returned to the solar neighborhood in 1996, though not close enough to generate the kind of activity of three years ago. Since that time activity has been very weak, but this year's moon sets favorably early, providing dark skies after midnight and an excellent opportunity to see what occurs. Little is expected, but as observers in 1998 realized, you just never know.

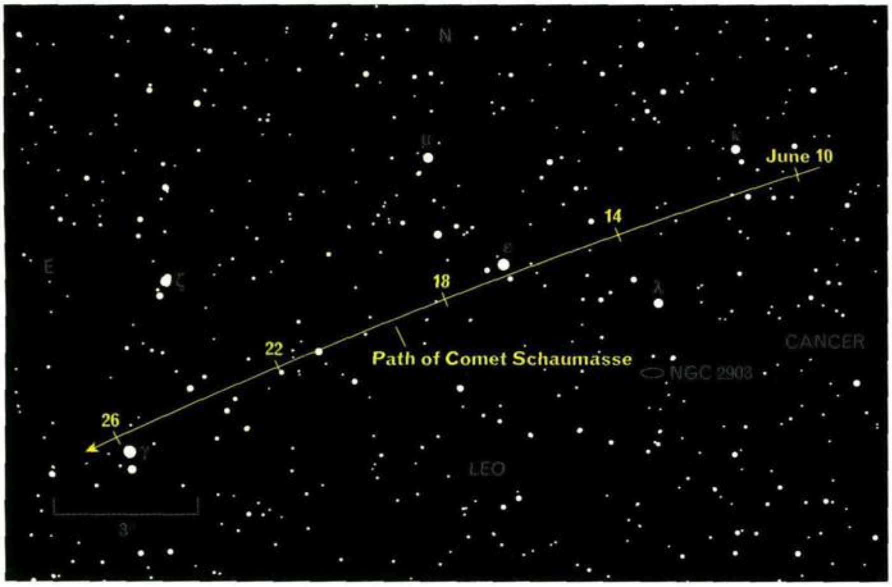
Atlas and Hercules

Atlas and Hercules lie adjacent to each other in the northeastern quadrant of the moon. Atlas is the larger crater, 55 miles across, and features a rough crater floor and a central ring of mountains instead of a central peak that is typical of craters of this size. Heavily terraced walls rise nearly 11,000 feet above the crater floor. Under certain lighting angles the crater floor of Atlas reveals three significant dark patches. Forty-five-mile wide Hercules is an older crater, revealed by the broken walls and floor created by later impacts. One significant crater is visible on the floor of Hercules. A smaller crater has intruded into the western wall, and another lies to the south. Watch the sunrise on the pair of craters around late May and late June.



Craters Atlas and Hercules (center) are visible northeast of Mare Serenitatis. Philippe Durville

June 21 will bring a total solar eclipse to portions of Africa and Madagascar. Christian Viladrich



Comet Schaumasse Succumbs

The curtains are closing on the remaining nights of periodic Comet 24P/Schaumasse's tour of the inner solar system. With a few notable exceptions like Halley, most returning comets don't even brighten into binocular range, let alone into backyard telescope grasp. Schaumasse is a fairly typical short-period comet. It peaked at 10th magnitude last month, and now masquerades in the evening sky like a faint Messier galaxy.

To get a good look at this ancient building block of our solar system, you'll have to drive out of town on a moonless night in the second week of June to reach dark skies. A 4-inch scope can pick up this interloper, but an 8-incher will be necessary if you want to see some structure. The sun's light evaporates away the ice, and scatters off the freed dust particles to create the inner coma and tail.

Between the 11th and 15th, Schaumasse lies within 4° of the bright spiral galaxy NGC 2903, located near the top of Leo's "sickle." The comet may be way closer to us, but it's just a small dirty snowball shining by reflected starlight at magnitude 11.5, and can't compete with the 9th-magnitude total brightness of the billions of stars that crowd the distant showpiece galaxy. Compare the two for size and shape. Schaumasse should be sharply defined on the sunward side, and more diffuse on the other. The tip of Leo's sickle, epsilon, provides us with an easy pointer to Schaumasse because between the 16th and the 18th, it's just one apparent moonwidth north of the comet.

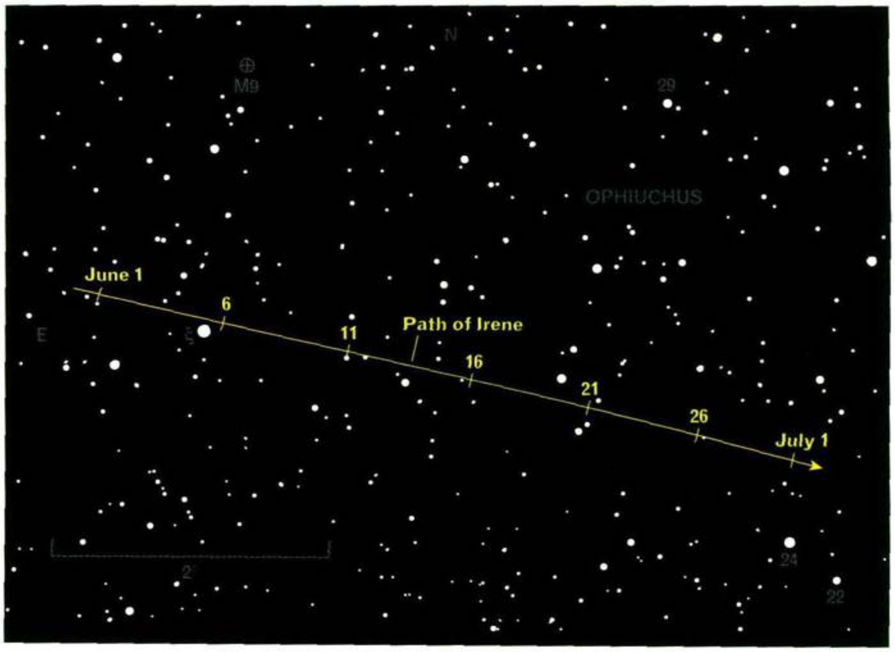
Here's a challenge: on the evening of the 27th, Schaumasse will be in the same field of view as NGC 3226/7, a galaxy pair of similar brightness, located near the beautiful double star Gamma (γ) Leonis. With the moon nearby, this event may be only for CCD-equipped amateurs. Earth orbits the sun on the inside track, so during the next couple of weeks we leave Schaumasse behind, trailing by almost half a lap, to disappear in the glare of our central luminary.

Asteroid 14 Irene Near Globulars

Crawling like an ant near the feet of the giant Serpent-Bearer Ophiuchus, the rocky asteroid Irene can only be spotted if you crouch down and take a closer look.

While you wait until late evening for Mars to rise higher in the southern sky, practice your star-hopping by seeking the 14th asteroid to have been discovered. At magnitude 9.4, Irene will be a bit of a challenge to sift out from the modestly rich starry background. If you can't resort to a detailed finder chart from an electronic atlas, use the tried and true method of making a sketch on one night and then revisiting the area a night or two later to see which "star" moved.

14 Irene starts the month just to the east of Xi (ξ) Ophiuchi, not far from the globular star cluster Messier 9. While you're in the area, check out this underrated cluster, which is a gem. **A**



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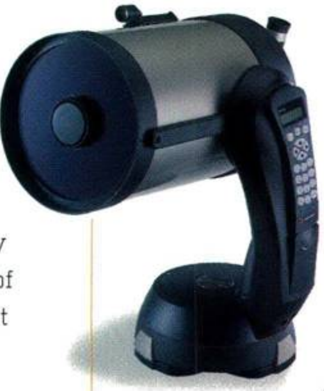

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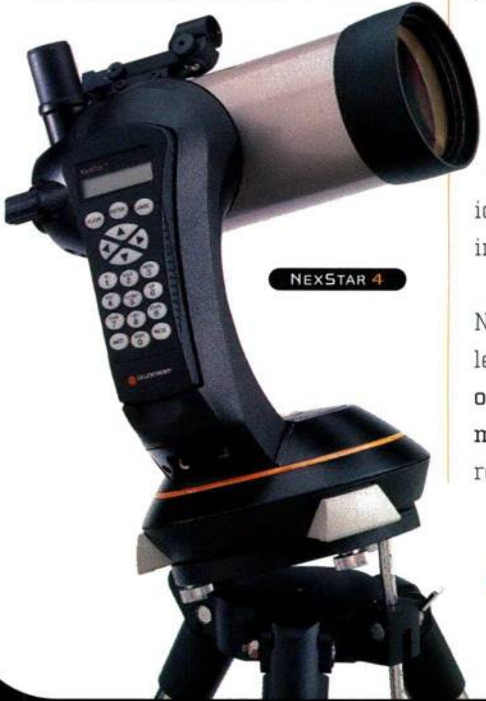

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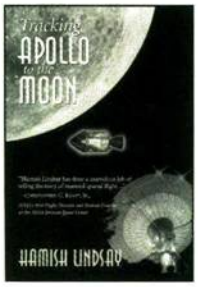

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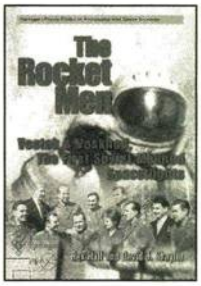

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EVERYTHING YOU NEED TO KNOW ABOUT BINOCULARS

Match binoculars to your eyes, interests, and observing habits.

by Phil Harrington

Whenever someone asks me to recommend a first telescope for a beginning stargazer, I immediately ask if he or she owns a pair of binoculars. And almost every time, the response is, "I don't want just binoculars. I want a telescope." Just binoculars? Give me a few minutes — I bet I can change your mind.

In spite of all the other tempting choices, binoculars remain one of astronomy's most useful and versatile observing tools. Not only are they portable and easy to use, but they also let us enjoy the night sky as it was meant to be viewed: with both eyes. As experienced observers know, binoculars are not just for beginners.

Anyone interested in astronomy should own at least one good pair of binoculars, for several reasons — the most obvious of which is portability. If you are like me, it seems that the clearest nights always occur during the week when I am too tired or short on time to set up

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my telescopes. Binoculars, on the other hand, are the ultimate "grab-and-go" tool, letting me tour the sky on the spur of the moment. Another advantage is that two eyes are better than one when it comes to observing. Indeed, some people experience up to a 40 percent increase in their detection of diffuse objects by using binoculars. Finally, binoculars offer a broad field of view that includes many widely-scattered objects that go unnoticed through the comparatively restricted fields of a telescope.

So there is more to binoculars than meets the eye — but the problem is that consumers must choose from hundreds on the market. It's a difficult decision. Read on for tips on which binoculars best suit your needs.

Two in One

Think of binoculars as two low-power refracting telescopes that happen to be strapped together. Light from the target enters through a pair of objective lenses, bounces through two identical sets of prisms, and exits through two eyepieces. Unlike telescopes, which usually flip the view, binoculars produce an upright image and provide wide-field views, which adds to their appeal — especially for beginners.

Just as the inventor of the telescope is not clearly known, whoever came up with the first pair of binoculars is also lost to history. Soon after the refractor telescope was invented, someone fastened two of the long tubes together to make binoculars. In 1894, Ernst Abbe, a German physicist and mathematician working for Carl Zeiss Optics, devised an ingenious "binocular prismatic telescope," which signaled two very important advances in binocular design: The light path ricocheted within a prism, reducing the binoculars' length while maintaining its focal length, and the prisms flipped the image right-side up.

Choosing Binoculars

Binoculars contain either roof or porro prisms. Roof-prism binoculars have sleek, straight barrels. Although they are light and compact, these binoculars are not ideal for astronomical use, for two reasons: a slightly dimmer image and higher cost. The dimmer image results from an aluminized coating on one internal surface of each prism. While the coating aids in bouncing light through the binoculars, it also diminishes the amount of light reaching the eyepieces. And the higher price reflects the precision required for assembly of roof-prism binoculars.

Avid stargazers should opt for the porro-prism design. When constructed of a high-quality glass, usually BaK-4, porro prisms have "total internal reflection," which means that all light entering the binoculars exits through the eyepieces. Porro-prism binoculars are often heavier and bulkier than roof-prism models, but produce brighter images.

No matter what their prism configuration, companies rate binoculars by two numbers, such as 7x35. The former specifies the combined power — or magnification — of the eyepiece and objective lenses, while the latter refers to the diameter (in millimeters) of the lens pointing to the sky. Magnification is a primary concern when selecting a pair of binoculars. Low-power binoculars (7x to 10x) are great for wide-field views of the Milky Way, but observers usually prefer higher-power glasses (11x and above) for close-up views of specific deep-sky objects. Keep in mind that the weight of binoculars increases proportionally with magnification and aperture. Most people can support 7x binoculars with minimal arm fatigue; increase the glasses to 10x, and the higher magnification also amplifies any motion, which often requires mechanical support of the binoculars. Before you buy, consider how you plan on supporting the binoculars at your observing site — and your age.

Consider the following points when purchasing binoculars:

- Lens coating type
- Prism glass type
- Alignment
- Focusing apparatus/ease of use
- Free of defects inside and out
- Proper interpupillary distance
- Tripod socket

What's Age Got To Do With It?

Good question. Just as most people need reading glasses as they get older, the adaptability of one's eyes to lighting changes decreases with age. The irises (the camera-diaphragm-like structures of the eyes) in younger people adapt quicker and dilate more completely, producing a larger range of pupil dilation when compared to someone closer to middle age. Therefore, properly-sized binoculars that fit your eyes will afford the best views. Match the diameter of the exit pupils (i.e., the light beam leaving the binoculars' eyepieces) to the diameter of your own pupils. An exit pupil that is too large lowers contrast between faint images and the background. Determine a binocular's exit pupil size by dividing the objective's diameter by the power. (For example, 50 ÷ 7 for a 7x50mm binoculars = 7.1mm exit pupil; likewise, with a 10x50mm binocular, the exit pupil is 5mm.)

Chances are that anyone younger than age 30 who observes under dark, rural skies will have pupils that dilate to about 7mm. In that case, look for binoculars with a matching 7mm exit pupil, such as 7x50, 10x70, or 11x80. Observers over 30 (or those in urban or suburban locations) may want to stick with binoculars whose exit pupil size is only 5 or 6mm. Remember that if the exit pupil is too large, the view will suffer from low image contrast, making it more difficult to see objects than through smaller, properly sized binoculars. Of course, the eye pupil measurement varies on an individual basis.

Good Eye Relief

A well-designed pair of binoculars have good eye relief, which is the distance that the binoculars must be held from the observer's eye in order to see the entire field of view. Binoculars with short eye relief must be held uncomfortably close to the face, posing a problem for eyeglass wearers. Excessive eye relief causes difficulty in centering and steadying the instrument. Most observers favor binoculars with eye relief between 14 and 20mm. Generally speaking, eye relief shrinks as magnification increases.

Skies Wide Open

One of the nicest features of binoculars is that they encompass a wide slice of sky in a single field of view, offering incomparable images of Milky Way star clouds, star clusters, and large nebulae. Field of view is stamped somewhere on the instrument, expressed in degrees or as a separation in feet at 1,000 yards (e.g., 325 feet at 1,000 yards). This second method means that a 325-foot ruler viewed from a thousand yards away would just squeeze into the eyepieces' field of view. Divide the number of feet by 52.5 to determine the field of view (e.g., 325 ÷ 52.5 = 6.2° of sky).

Let's Go Shopping!

Decide which sizes and models meet your budget and go shopping. Browsing the Internet or catalogs has advantages, but unless you know exactly what you want, it's best to check out the binoculars in person. I recommend comparing several brands side-by-side.

Begin with the optics. You'll want coated lenses. Multiple coatings improve light transmission and reduce internal scattering. Insist on fully-coated, or better yet — fully multi-coated — optics. Some manufacturers claim that ruby-colored coatings excel at reducing glare in very bright light. I've found these to be of no benefit to stargazers.

Next, check the binoculars' optical alignment: While looking at a distant object with both eyes, cover one side of the binoculars with your palm. Now quickly remove your hand. If any misalignment exists, you'll see two images for an instant before your brain snaps them together.

After the alignment check, determine what type of glass — BaK-4 (barium crown) or BK-7 (borosilicate) — was used, especially in the porro prisms. Generally, BaK-4 prisms yield brighter, sharper images than BK-7 prisms.

Most binoculars have a knurled focusing wheel between the barrels. Others have separately-focusing eyepieces. Either way, choose a focusing device that moves smoothly. Center focusing is more convenient if you expect to support the binoculars by hand and trade them between observers. Individually focusing eyepieces are usually more rugged and less prone to misalignment with age. Avoid "fast-focus" thumb levers if you plan to dedicate those binoculars to stargazing. Thumb levers tend to favor coarse focusing — sometimes at the expense of accurate focusing.

Next, hold the binoculars up to a light and look into the front end (the objective lenses) for scratches and stains. Check also that the inside of the barrels look uniformly dark and free of dust, adhesive, or metal shavings. Make sure that the central hinge adjusts to comfortably fit the distance between your eyes and those of whomever else may use the binoculars on a regular basis.

Also, buy binoculars with a tripod socket. I recommend using some sort of tripod, regardless of the size of the binoculars. Not only does this make it easier to switch between looking at a star chart and through the binoculars, it also provides a very steady view.

Image-Stabilized Binoculars

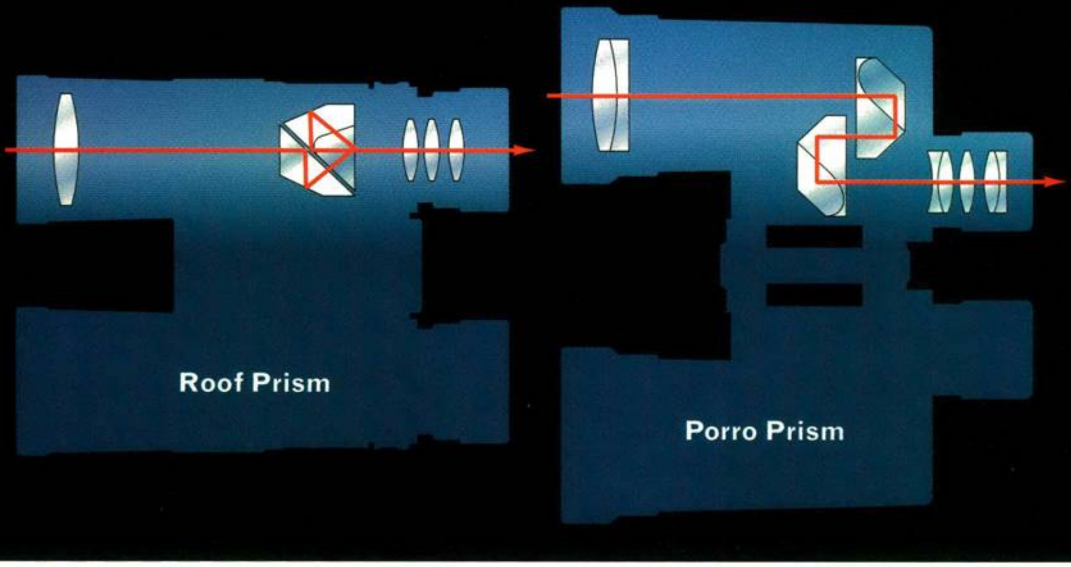
Owners of image-stabilized binoculars offered by Zeiss, Canon, and Fujinon rave about them. Canon and Fujinon brands stabilize the image electronically; Zeiss stabilization is done mechanically. Either way, the technology is terrific — as are the optics in all three brands. Despite the comparatively small apertures of this genre, the steadier image allows views that are superior to some larger, conventional binoculars. Unfortunately, the price tags are equally impressive, with even the smallest models costing more than $600.

But even less expensive binoculars can take you on many wonderful voyages throughout the universe. After all, the best binoculars are those that are used the most.

Phil Harrington loves all kinds of astronomical equipment. A stargazer for more than 30 years, Phil is the author of several books on astronomy, including Touring the Universe Through Binoculars Atlas, *on CD ROM. Visit his website at http://philharrington.net.*

Binocular Prism Designs

Light bounces differently through binoculars according to the juxtaposition of the prisms. The roof-prism design is more compact, but also more expensive; porro-prism binoculars are generally preferred for astronomical use because they provide total internal reflection.



Astronomy: Rick Johnson

Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
Bausch & Lomb											
Legacy	7	35	11.0	C	5.0	9	22	Yes	BaK-4	MC	$100
Discoverer	7	42	8.0	C	6.0	20	29	No	Roof	MC	$350
Custom	8	36	6.5	C	4.5	19	22	Yes	BaK-4	MC	$290
Legacy	8	40	8.5	C	5.0	9	24	Yes	BaK-4	MC	$100
Custom	10	40	5.2	C	4.0	19	29	Yes	BaK-4	MC	$300
Discoverer	10	42	6.5	C	4.2	16	29	No	Roof	MC	$360
Legacy	10	50	7.5	C	5.0	9	28	Yes	BaK-4	MC	$130
Brunton											
Eterna	7	42	7.9	C	6.0	20	30	No	Roof	FMC	$400
Lite-Tech	7	50	7.0	C	7.1	24	39	Yes	BaK-4	FC	$150
Eterna	10	42	6.4	C	4.2	18	30	No	Roof	FMC	$400
Lite-Tech	10	50	6.5	C	5.0	19	39	Yes	BaK-4	FC	$150
Eterna	12	42	5.2	C	3.5	18	30	No	Roof	FMC	$400
Bushnell											
Marine	7	50	7.0	I	7.1	n/s	37	Yes	BaK-4	FC	$140
Natureview	8	42	8.0	C	5.3	19	26	Yes	BK-7	FC	$100
Natureview	10	42	6.0	C	4.2	19	25	Yes	BK-7	FC	$120
Canon											
IS (Image Stabilizer)	10	30	6.0	C	3.0	15	21	No	Roof	FMC	$500
IS (Image Stabilizer)	12	36	5.6	C	3.0	15	31	No	Roof	FMC	$800
IS (Image Stabilizer)	15	45	4.5	C	3.0	15	36	No	Roof	FMC	$1,000
IS (Image Stabilizer)	15	50	4.5	C	3.3	15	42	No	Roof	FMC	$1,300
IS (Image Stabilizer)	18	50	3.7	C	2.8	15	42	No	Roof	FMC	$1,500
Celestron											
Bird Watcher	7	35	10.0	C	5.0	14	20	Yes	BaK-4	MC	$100
Enduro	7	35	9.2	C	5.0	11	22	Yes	BK-7	FC	$50
Enduro	7	50	6.8	C	7.1	13	28	Yes	BK-7	FC	$50
Ultima	7	50	7.0	C	7.1	20	27	Yes	BaK-4	FMC	$240
Watersport	7	50	7.0	C	7.1	19	39	No	BaK-4	FC	$90
Bird Watcher	8	40	9.0	C	5.0	14	21	Yes	BaK-4	MC	$110
Enduro	8	40	8.2	C	5.0	12	25	Yes	BK-7	FC	$50
Ultima	8	40	6.6	C	5.0	19	21	Yes	BaK-4	FMC	$200
Enduro	8	56	6.0	C	7.0	21	36	Yes	BK-7	FC	$85
Ultima	8	56	6.1	C	7.0	21	31	Yes	BaK-4	FMC	$260
Ultima	9	63	5.4	C	7.0	21	35	Yes	BaK-4	FMC	$320
Bird Watcher	10	50	6.5	C	5.0	13	26	Yes	BaK-4	MC	$120

KEY TO BINOCULARS BUYER'S GUIDE

Prism type column:

Binoculars feature one of two prism configurations, roof and porro styles. Many roof-style binoculars appear in this chart, but overall, porro BaK-4 prisms are recommended for astronomical use. Porro prisms are made of either BaK-4 (barium crown) or BK-7 (borosilicate) glass. The type of glass used in the roof prisms is not specified.

Exit pupil column:

- Some manufacturers did not provide complete statistics.
- "Not supplied" is listed as n/s.

Focus column:

Two different letter designations are used.

- "C" indicates a central focusing knob.
- "I" means that the eyepieces focus individually.

Coating column: (four types of coating)

FMC = fully, multi-coated (preferred)
MC = multi-coated
FC = fully coated
C = coated

Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
Enduro	10	50	7.0	C	5.0	13	28	Yes	BK-7	FC	$50
Ultima	10	50	5.0	C	5.0	21	27	Yes	BaK-4	FMC	$240
Watersport	10	50	6.5	C	50.	19	40	No	BaK-4	FC	$100
Giant Deluxe	20	80	3.5	C	4.0	16	5.6 lbs	Yes	BaK-4	MC	$430
Eagle											
Optics Voyager	8	42	6.6	C	5.3	18	21	Yes	BaK-4	FMC	$180
Optics Voyager ED	9.5	44	6.0	C	4.6	14	24	Yes	BaK-4	FMC	$280
Optics Ranger	10	42	5.0	C	4.2	15	23	Yes	Roof	FMC	$370
Optics Ranger	10	50	5.0	C	5.0	17	28	Yes	Roof	FMC	$400
Edmund											
Edmund	7	50	7.0	C	7.1	17	29	No	BK-7	FC	$90
Fujinon											
MT-SX	7	50	7.5	I	7.1	12	45	Yes	BaK-4	FMC	$400
FMT-SX	7	50	7.5	I	7.1	23	50	Yes	BaK-4	FMC	$500
MT-SX	10	70	5.3	I	7.0	12	76	Yes	BaK-4	FMC	$500
FMT-SX	10	70	5.3	I	7.0	23	76	Yes	BaK-4	FMC	$600
Techno-Stabi	14	40	4.0	C	2.9	10	43	No	Roof	FMC	$1,100
MT-SX	15	80	4.0	I	5.3	16	16 lbs	Yes	BaK-4	FMC	$3,000
MT-SX	16	70	4.0	I	4.4	12	76	Yes	BaK-4	FMC	$560
FMT-SX	16	70	4.0	I	4.4	16	76	Yes	BaK-4	FMC	$600
MT-SX	25	150	2.7	I	6.0	19	41 lbs	Yes	BaK-4	FMC	$5,500
ED-SX	25	150	2.7	I	6.0	19	41 lbs	Yes	BaK-4	FMC	$10,000
EM-SX	25	150	2.7	I	6.0	19	43 lbs	Yes	BaK-4	FMC	$15,000
ED-SX	40	150	1.7	I	3.8	15	41 lbs	Yes	BaK-4	FMC	$12,000
Kowa											
7x40 ZCF	7	40	7.5	C	5.7	23	28	No	BaK-4	FMC	$170
8x45 DCF	8	45	6.2	C	5.6	20	29	No	Roof	FMC	$270
10x40 ZCF	10	40	6.3	C	4.2	17	28	No	BaK-4	FMC	$180
10x45 DCF	10	45	6.0	C	4.5	12	30	No	Roof	FMC	$280
Leica											
Trinovid 7x42 BN	7	42	8.0	C	6.0	16	31	No	Roof	FMC	$900
Trinovid 8x42 BA	8	42	7.4	C	5.3	16	31	No	Roof	FMC	$950
Trinovid 8x50 BA	8	50	6.6	C	6.5	16	41	No	Roof	FMC	$1,050
Trinovid 10x42 BN	10	42	6.3	C	4.2	13	31	No	Roof	FMC	$1,000
Trinovid 10x50 BA	10	50	6.6	C	5.0	14	41	No	Roof	FMC	$1,100
Trinovid 12x50 BA	12	50	5.7	C	4.2	11	41	No	Roof	FMC	$1,250
Leupold											
Wind River 8x42	8	42	6.5	C	5.3	16	25	No	BaK-4	MC	$350
Gold Ring 10x40	10	40	5.0	C	4.0	17	29	No	Roof	FMC	$770
Wind River 10x50	10	50	5.3	C	5.0	16	32	No	BaK-4	MC	$400
Gold Ring 12x50	12	50	4.0	C	4.2	17	37	No	Roof	FMC	$880
Meade											
Infinity 7x35WA	7	35	9.2	C	5.0	11	24	No	BK-7	FC	$60
Mirage 7x35	7	35	8.0	C	5.0	14	21	No	BK-7	C	$35
Travel View 7x35WA	7	35	9.2	C	5.0	12	23	No	BK-7	FC	$70
Safari Pro 7x36WA	7	36	9.3	C	5.1	19	24	Yes	BaK-4	MC	$150
RainForest Pro 7x42WA	7	42	9.4	C	6.0	16	34	No	Roof	MC	$430
Infinity 8x40WA	8	40	8.2	C	5.0	11	26	No	BK-7	MC	$60
Safari Pro 8x42WA	8	42	8.2	C	5.3	19	26	Yes	BaK-4	MC	$160
RainForest Pro 8x56	8	56	6.5	C	7.0	23	39	No	Roof	MC	$450

Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
Safari Pro 10x42	10	42	6.1	C	4.2	16	24	Yes	BaK-4	MC	$170
Infinity 10x50WA	10	50	7.0	C	5.0	13	30	No	BK-7	FC	$70
Mirage 10x50	10	50	5.7	C	5.0	13	25	No	BK-7	C	$40
Safari Pro 10x50WA	10	50	6.5	C	5.0	16	32	Yes	BaK-4	MC	$180
Travel View 10x50WA	10	50	7.0	C	5.0	13	29	No	BK-7	FC	$80
Travel View 12x50WA	12	50	5.4	C	4.2	13	30	No	BK-7	FC	$60
Minolta											
Activa 7x35W	7	35	9.3	C	5.0	19	24	Yes	BaK-4	FMC	$150
Classic II 7x35W	7	35	9.3	C	5.0	12	20	Yes	BK-7	FC	$70
Activa 8x40W	8	40	8.2	C	5.0	18	26	Yes	BaK-4	FMC	$150
Classic II 8x40W	8	40	8.2	C	5.0	12	23	Yes	BK-7	FC	$70
Activa 7x50	7	50	6.3	C	7.1	24	31	Yes	BaK-4	FMC	$170
Classic II 7x50	7	50	7.0	C	7.1	19	27	Yes	BK-7	FC	$90
Activa 10x50W	10	50	6.5	C	5.0	19	31	Yes	BaK-4	FMC	$180
Classic II 10x50W	10	50	6.5	C	5.0	12	27	Yes	BK-7	FC	$80
Activa 12x50W	12	50	5.5	C	4.2	14	31	Yes	BaK-4	FMC	$190
Miyauchi											
BS-77	20	77	2.5	I	3.9	20	6.6 lbs	Yes	BaK-4	FMC	$1,000
BJ100iA (Semi-apochromatic)	20	100	2.5	I	5.0	25	10 lbs	Yes	BaK-4	FMC	$2,900
BJ100iBF (fluorite)	20	100	2.5	I	5.0	25	13.2 lbs	Yes	BaK-4	FMC	$3,700
BR-141	25	141	2.6	I	n/s	n/s	26 lbs	Yes	BaK-4	FMC	$11,400
(Eyepieces sold separately)											
Nikon											
Naturalist IV	7	35	9.3	C	5.0	12	23	Yes	BaK-4	MC	$120
Egret II	8	40	8.2	C	5.0	12	25	Yes	BaK-4	MC	$120
Shoreline	7	50	6.4	C	7.1	20	32	Yes	BaK-4	MC	$140
7x50 Sports and Marine	7	50	7.5	C	7.1	18	41	Adapter req'd	BaK-4	MC	$240
IF SP 7x50 (Prostars)	7	50	7.3	I	7.1	15	48	Adapter req'd	BaK-4	FMC	$900
Superior E 10x42	10	42	6.0	C	4.2	17	24	Adapter req'd	BaK-4	FMC	$800
Lookout IV	10	50	6.5	C	5.0	20	32	Yes	BaK-4	MC	$130
Fieldmaster	12	50	5.5	C	4.2	9	32	Yes	BaK-4	MC	$150
IF SP 10x70 (Astroluxe)	10	70	5.1	I	7.0	15	70	Adapter req'd	BaK-4	FMC	$1,200
Superior E 12x50	12	50	5.0	C	4.2	17	30	Adapter req'd	BaK-4	FMC	$850
IF SP 18x70	18	70	4.0	I	3.9	15	68	Adapter req'd	BaK-4	FMC	$1,250
20x120 III	20	120	3.0	I	6.0	21	34 lbs	Pedestal base sold separately	BaK-4	FMC	$5,500
Oberwerk											
8x60	8	60	5.5	C	7.2	18	37	Yes	BaK-4	FC	$110
9x60	9	60	5.5	C	6.5	16	37	Yes	BaK-4	FC	$110
11x56	11	56	6.0	C	5.1	19	36	Yes	BaK-4	FMC	$100
12x60	12	60	5.0	C	4.6	14	37	Yes	BaK-4	FC	$110
15x60	15	60	4.1	C	3.8	12	37	Yes	BaK-4	FC	$110
20x60	20	60	3.0	C	3.0	10	37	Yes	BaK-4	FC	$110
15x70	15	70	4.3	C	4.6	15	53	Yes	BaK-4	FMC	$150
Military	25 and 40 (turret eyepieces)	100	2.5/1.5	I	4/2.5	14/8	26.5 lbs	Yes	BaK-4	MC	$1,400 (w/tripod)
Orion											
Scenix	7	50	7.1	C	7.1	17	28	Yes	BaK-4	FC	$80

Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
UltraView	7	50	6.5	C	7.1	22	32	Yes	BaK-4	FMC	$160
Vista	7	50	6.0	C	7.1	22	28	Yes	BaK-4	FMC	$200
Scenix	8	40	9.0	C	5.0	14	24	Yes	BaK-4	FC	$70
UltraView	8	42	8.2	C	5.3	22	27	Yes	BaK-4	FMC	$140
Vista	8	42	6.5	C	5.25	18	22	Yes	BaK-4	FMC	$200
Orion Mini Giant	9	63	5.0	C	7.0	18	36	Yes	BaK-4	FMC	$200
Scenix	10	50	7.0	C	5.0	14	28	Yes	BaK-4	FC	$80
UltraView	10	50	6.5	C	5.0	22	32	Yes	BaK-4	FMC	$160
Vista	10	50	5.3	C	5.0	16	28	Yes	BaK-4	FMC	$200
Little Giant II	11	70	4.5	C	6.4	18	47	Yes	BaK-4	FMC	$260
Giant	11	80	4.5	C	7.0	16	77	Yes	BaK-4	FMC	$390
Little Giant II	15	70	4.0	C	4.7	8	47	Yes	BaK-4	FMC	$260
Giant	16	80	3.5	C	5.0	16	77	Yes	BaK-4	FMC	$390
Little Giant II	20	70	3.0	C	3.5	8	47	Yes	BaK-4	FMC	$260
Giant	20	80	3.5	C	4.0	15	77	Yes	BaK-4	FMC	$390
Supergiant	25	100	2.6	C	4.0	10	7.5 lbs	Yes	BaK-4	FMC	$1,150
Parks											
GR	7	50	6.8	C	7.1	20	24	Yes	BaK-4	FMC	$170
TNE	7	50	6.0	C	7.1	25	27	Yes	BaK-4	FMC	$280
Waterproof	7	50	7.0	C	7.1	21	31	Yes	BaK-4	MC	$280
ZWCF	8	42	8.2	C	5.25	22	24	Yes	BaK-4	FMC	$170
GR	10	50	5.3	C	5.0	18	25	Yes	BaK-4	FMC	$170
ZWCF	10	52	6.5	C	5.2	22	28	Yes	BaK-4	FMC	$200
Deluxe Giant	10	70	5.0	C	7.0	20	60	Yes	BaK-4	FMC	$300
Deluxe Giant	11	80	4.5	C	7.3	20	5.3 lbs	Yes	BaK-4	FMC	$400
Deluxe Giant	15	80	3.5	C	5.3	18	5.3 lbs	Yes	BaK-4	FMC	$440
Deluxe Giant	20	80	3.5	C	4.0	16	5.4 lbs	Yes	BaK-4	FMC	$500
Deluxe Giant	25	100	2.6	C	4.0	10	7.6 lbs	Yes	BaK-4	FMC	$1,900
Pentax											
PCF V	7	50	6.2	C	7.1	20	34	Yes	BaK-4	MC	$170
PCF V	8	40	6.3	C	5.0	20	27	Yes	BaK-4	MC	$170
PCF V	10	40	5.0	C	4.0	17	27	Yes	BaK-4	MC	$180
PCF V	12	50	4.2	C	4.2	20	33	Yes	BaK-4	MC	$190
PCF V	16	60	2.8	C	3.8	20	43	Yes	BaK-4	MC	$250
PCF V	20	60	2.5	C	3.0	21	43	Yes	BaK-4	MC	$260
Pro-Optic											
Pro-Optic Provis	7	50	6.0	C	7.1	23	28	Yes	BaK-4	FMC	$110
Pro-Optic Provis	8	42	6.5	C	5.3	16	22	Yes	BaK-4	FMC	$130
Pro-Optic Provis	10	50	5.3	C	5.0	16	28	Yes	BaK-4	FMC	$125
Pro-Optic Giant	11	70	4.0	C	6.4	21	45	Yes	BaK-4	FMC	$160
Pro-Optic Giant	11	80	4.2	C	7.3	14	5.3 lbs	Yes	BaK-4	FMC	$250
Pro-Optic Ultra Giant	14	100	3.3	C	7.1	14	8.5 lbs	Yes	BaK-4	MC	$850
Pro-Optic Giant	16	70	3.6	C	4.4	11	45	Yes	BaK-4	FMC	$170
Pro-Optic Giant	20	80	3.3	C	4	14	5.3 lbs	Yes	BaK-4	FMC	$260
Pro-Optic Ultra Giant	25	100	2.5	C	4	10	8.5 lbs	Yes	BaK-4	MC	$900
Steiner											
Military/Marine	7	50	7.0	I	7.1	22	37	Yes	BaK-4	FMC	$470
Admiral-Gold 7x50	7	50	7.3	I	7.1	22	37	Yes	BaK-4	FMC	$770
Nighthunter	7	50	7.1	I	7.1	21	33	No	BaK-4	FMC	$670
Predator	8	42	7.0	C	5.3	23	24	Yes	Roof	FMC	$700
Nighthunter	8	56	6.3	I	7.0	21	41	No	BaK-4	FMC	$800

Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
Big Horn	9	40	5.7	I	4.4	20	26	Yes	BaK-4	FMC	$380
Big Horn	9	40	5.7	I	4.4	20	26	Yes	BaK-4	FMC	$500
Predator	10	42	5.6	C	4.2	16	25	Yes	Roof	FMC	$740
Military/Marine	10	50	6.2	I	5.0	17	36	Yes	BaK-4	FMC	$470
Nighthunter	10	50	6.0	I	5.0	21	35	No	BaK-4	FMC	$700
Nighthunter	12	56	4.9	I	4.7	22	41	No	BaK-4	FMC	$850
Senator	15	80	3.7	I	5.3	13	56	Yes	BaK-4	FMC	$1,000
Senator	20	80	3.7	I	4.0	13	56	Yes	BaK-4	FMC	$1,000
Swarovski											
Habicht 7x42	7	42	6.4	C	6.0	14	24	Yes	BaK-4	MC	$500
Habicht 7x42GA	7	42	6.4	C	6.0	14	27	Yes	BaK-4	MC	$650
SLC 7x42B	7	42	8.0	C	6.0	19	34	Yes	Roof	FMC	$850
SLC 7x50B	7	50	7.1	C	7.1	23	41	Yes	Roof	FMC	$1,000
SLC 8x50B	8	50	7.0	C	6.3	21	41	Yes	Roof	FMC	$1,100
SLC 8x56B	8	56	6.6	C	7.0	22	47	Yes	Roof	FMC	$1,250
EL 8.5x42	8.5	42	7.4	C	4.9	18	29	No	Roof	FMC	$1,300
Habicht 10x40W	10	40	6.2	C	4.0	13	24	No	BaK-4	MC	$600
Habicht 10x40W GA	10	40	6.2	C	4.0	13	28	No	BaK-4	MC	$680
EL 10x42	10	42	6.3	C	4.2	15	28	No	Roof	FMC	$1,350
SLC 10x42B	10	42	6.3	C	4.2	12	31	Yes	Roof	FMC	$900
SLC 10x50B	10	50	6.4	C	5.0	17	42	Yes	Roof	FMC	$1,100
SLC 15x56B	15	56	4.4	C	3.7	13	47	Yes	Roof	FMC	$1,600
Swift											
Aerolite 7x35	7	35	6.8	C	5.0	14	20	No	BK-7	FC	$55
Aerolite 7x35W	7	35	9.5	C	5.0	9	24	No	BK-7	FC	$60
Ultra Lite	7	42	7.0	C	6.0	25	21	Yes	BaK-4	FMC	$240
Aerolite 7x50	7	50	7.1	C	7.1	14	39	No	BK-7	FC	$70
Sea Wolf	7	50	7.1	C	7.1	13	33	Yes	BK-7	FC	$210
Sea Hawk	7	50	7.5	I	7.1	19	42	Yes	BaK-4	FC	$270
Aerolite Birder 8x40	8	40	9.0	C	5.0	16	33	No	BK-7	FC	$60
Plover	8	40	9.0	C	5.0	14	25	Yes	BaK-4	FC	$100
Ultra Lite	8	42	6.6	C	5.3	22	21	Yes	BaK-4	FMC	$260
Ultra Lite ED	8	44	6.5	C	5.5	21	25	Yes	BaK-4	FMC	$400
Audubon	8.5	44	8.2	C	5.2	15	29	No	BaK-4	FMC	$270
Audubon ED	8.5	44	8.2	C	5.2	15	29	No	BaK-4	FMC	$550
Ultra Lite	9	63	5.4	C	7.0	21	25	Yes	BaK-4	FMC	$500
Ultra Lite	10	42	6.6	C	4.2	13	21	Yes	BaK-4	FMC	$270
Aerolite 10x50	10	50	5.2	C	5.0	13	37	No	BK-7	FC	$70
Cougar	10	50	7.0	C	5.0	14	29	Yes	BaK-4	FC	$120
Kestrel	10	50	7.0	C	5.0	15	32	Yes	BaK-4	FMC	$300
Sea Wolf	10	50	7.1	C	5.0	19	33	Yes	BK-7	FC	$240
Observer	11	80	4.5	C	7.3	16	78	Yes	BaK-4	FC	$400
Vanguard	15	60	4.2	C	4.0	10	40	Yes	BK-7	MC	$240
Satellite	20	80	3.5	C	4.0	16	78	Yes	BaK-4	FC	$430
Takahashi											
Astronomer	22	60	2.1	I	2.7	18	76	Yes	BaK-4	FMC	$1,100
Vixen/Orion											
Vixen/Orion	20	125	3.0	I	6.2	20	24 lbs	Yes	BaK-4	MC	$4,000
Vixen/Orion	25 – 75	125	1.6 – 0.8	I	4.2	20	24 lbs	Yes	BaK-4	MC	$4,500
Binocular Telescope	36	80	1.1	I	2.2	n/s	11 lbs	Yes	BaK-4	MC	$900

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Model	Magnification (Eyepiece)	Objective Lens (mm)	Field of View (degrees)	Focus	Exit Pupil (mm)	Eye Relief (mm)	Weight (oz)	Tripod Socket	Prism Type	Coating	Price
Zeiss											
7x42 B/GA T* ClassiC	7	42	9.4	C	6.0	19	28	Yes	Roof	FMC	$850
7x50 B/GA T* ClassiC	7	50	8.2	I	7.1	18	41	Yes	BaK-4	FMC	$1,100
Victory 8x40 BT	8	40	8.5	C	5.0	16	26	Yes	Roof	FMC	$1,000
8x56 B/GA T*ClassiC	8	56	6.9	C	7.0	15	36	Yes	Roof	FMC	$1,100
Victory 8x56 BT	8	56	8.3	C	7.0	18	41	Yes	Roof	FMC	$1,300
10x40 B/GA T* ClassiC	10	40	6.3	C	4.0	15	27	Yes	Roof	FMC	$800
Victory 10x40 BT	10	40	6.3	C	4.0	15	26	Yes	Roof	FMC	$1,000
Victory 10x56 BT	10	56	6.9	C	5.6	16	42	Yes	Roof	FMC	$1,400
15x60 B/GA T* ClassiC	15	60	4.3	C	4.0	15	56	Yes	BaK-4	FMC	$1,900
20x60 S	20	60	3.1	C	3.0	14	57	Yes	BaK-4	FMC	$4,500

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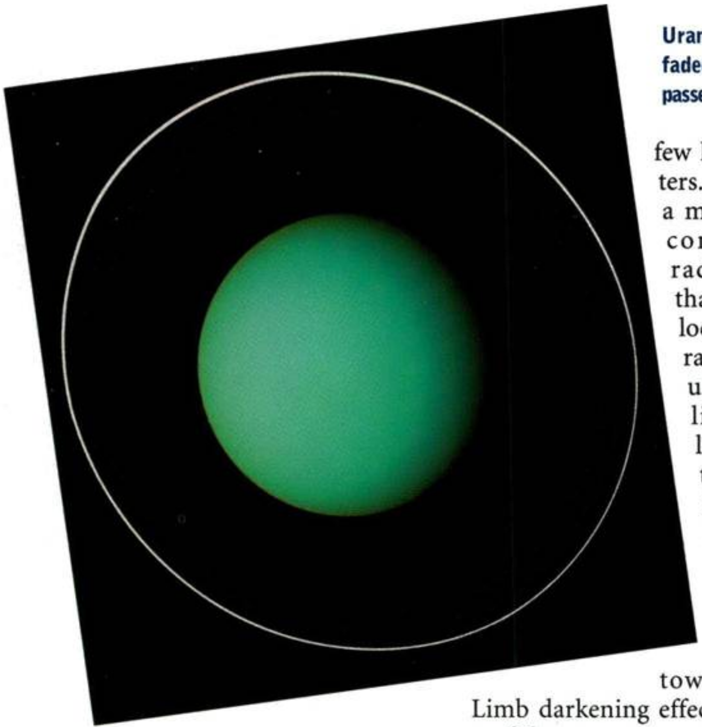


Uranus reveals its dark, faded limb to a wandering passerby. NASA/Voyager 2

Why do the gas giant planets appear to have bright, sharp-cut edges, rather than gradually fading out like the sun? — *Neil Shutterwood, Essex, England*

It's true that stars, which are gaseous throughout, are darkened at their edge (also called the "limb"). In fact, this effect (appropriately called "limb darkening") is quite obvious on the sun, where the solar limb is notably darker and redder than the center of the solar disk. The sun's apparent surface only looks *solid* because the gas is highly opaque and difficult for visible light to penetrate. (Note: To avoid risk of permanent eye damage, including blindness, never look directly at the sun without protective equipment.)

Still, the gas that makes up the sun is not perfectly opaque. In fact, our vision penetrates the solar surface by a few hundred kilometers. But this is such a minuscule depth compared to the radius of the sun that the solar limb looks as sharp as a razor. The secret to understanding limb darkening lies with the fact that, within those few hundred kilometers, the temperatures of the solar gases measurably increase toward the center. Limb darkening effects are extremely useful to astronomers, as they can be used to determine temperature gradients — the rate at which temperature increases with depth — near the surface of the sun.

When we look to the solar limb, rather than the center of the solar disk, our line of sight penetrates the cooler, upper layers of the sun at a sharp angle. Consequently, we do not peer as deeply into the hot interior of the sun. Thus, gases at the solar limb appear on the average to be cooler — therefore dimmer and redder — than at the center of the apparent solar disk.

Although the visible surfaces of the gas giant planets are composed of clouds and haze, they are also not perfectly opaque. As a result, the giant planets also exhibit subtle limb darkening. The darkening is not easy to see in a small telescope, but an examination of many Hubble or other space-based images will quite notably show the effect.

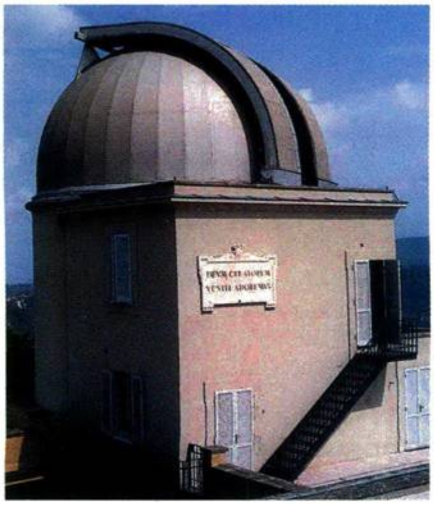
So the answer to your question really lies between two extremes. Though the sun darkens considerably near its limb, the edge is still quite sharp. And though the giant planets appear to have bright, sharp limbs, they still manifest the signs of limb darkening on closer inspection. The same effect is visible in both cases, just in varying degrees. — *Jim Kaler, University of Illinois. Visit the "Star of the Week" on his website at www.astro.uiuc.edu/~kaler/sow/sow.html.*

Do you think religion and astronomy will ever achieve harmony? What's preventing it today? — *Joseph Daudish, Westchester, Illinois*

I think that religion and astronomy have already achieved harmony. I've met astronomers from just about every religious tradition I can think of: We all find that our research in astronomy enriches our faith, while our faith helps motivate what we do and why we do it. And my impression is that the percentage of astronomers who are churchgoers is about the same as that of the general public.

We often hear about some "fundamentalists" who are opposed to science. But there are also "fundamentalists of science" who despise religion. Both groups are hardly typical of the vast majority of us who practice religion or science. A faith that is afraid of truth has no faith. Science that is dedicated to finding the truth is dedicated

The Specola Vaticana overlooks Lake Albano, 13 miles southeast of Rome. Emmanuel Carreira



to a transcendence greater than itself. — *Brother Guy Consolmagno S.J., Vatican Observatory Research Group, Steward Observatory. He is the author of* Brother Astronomer: Adventures of a Vatican Scientist *(McGraw Hill, 2000).*

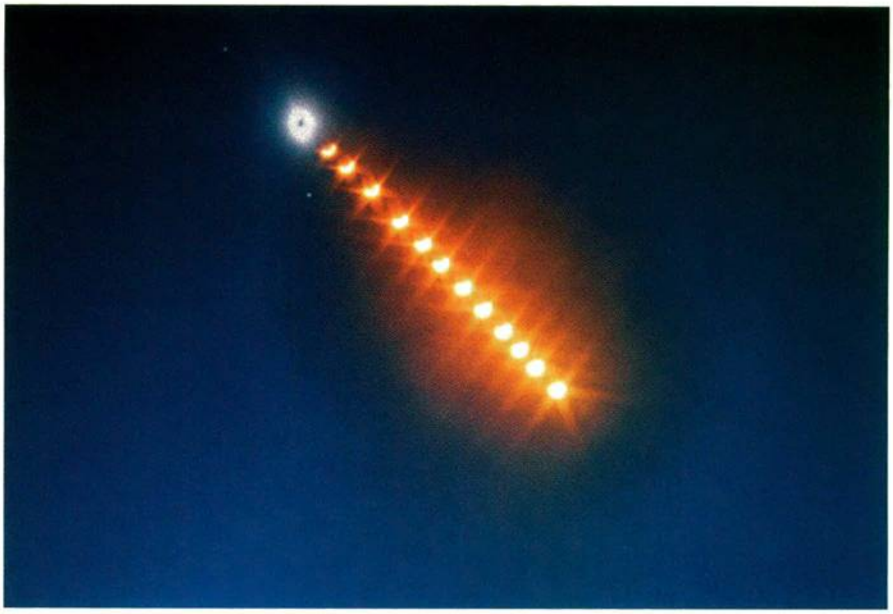
I want to record the June, 2001 eclipse with my digital camcorder. Can you recommend a mechanical or electric motor drive mount with a tripod thread for a camcorder or 35mm camera? I'd prefer it to be small and light for travel. — *Fred Vroom, Tallahassee, Florida*

Keep your eclipse plans simple. A digital camcorder's clarity and sensitivity should easily catch all phases of the eclipse without the extra weight and expense of a motor drive, provided you use a safe solar filter when the sun isn't completely covered. Many advertisers in *Astronomy* sell metal-coated solar filters that you can cut to fit the front lens of your camera.

Set the camera up on a sturdy tripod and shoot the eclipse in stages. The best tripod is a "fluid-head" type, designed to provide the smooth motions required during video work. A socket on the video camera's base will thread directly to the tripod. Record the partial phases of the eclipse through a solar filter at five-minute intervals to create a time-lapse sequence, while keeping the sun's disk centered during subsequent 30-second recording sessions.

Be sure to remove the solar filter at the moment of totality, when the moon's disk completely covers the sun. You'll want to capture this stage of the eclipse in its entirety. Vary the camera's gain and field of view to record all aspects of totality, including the extensive solar corona as well as nearby Jupiter and Mercury.

If you'd still prefer a portable, motorized equatorial drive mount, consider the Takahashi Teegul camera mount system (Texas Nautical Repair; 713-529-3551) or the Series II German Equatorial mount (Pocono Mountain Optics; 570- 842-1500). The Takahashi starts at around $850, while the Series II costs between $300 and $400. — *John Shibley, Contributing Editor*



Exercise extreme caution when capturing your own time-lapse solar eclipse shots. Trudy Koller-Anes

Considering that Earth reaches perihelion during the summer in the Southern Hemisphere, does that mean summer is hotter in the Southern Hemisphere? — *Joao Miguel Matos, Setubal, Portugal*

It's true that Earth currently reaches perihelion — its closest approach to the sun — in January. It reaches aphelion — its greatest distance from the sun — in July. Nonetheless, be careful to note that these dates of occurrence are subject to change. The aphelion/perihelion points are slowly shifting and will occur during different seasons throughout a 21,000-year cycle. For instance, in 4081 B.C., Earth reached perihelion on the autumnal equinox. And in A.D. 6427, Earth will reach perihelion on the vernal equinox.

Having said all that, one might logically conclude that Earth's varying distance should result in significant temperature changes. After all, you'll be hot if you stand next to a fire and noticeably cooler if you walk far away from it. But any such effect on Earth as it orbits the sun is negligible. The difference between Earth's perihelion and aphelion distance from the sun is really only about three percent.

Astronomers define the astronomical unit (AU) as the mean Earth-sun distance — approximately 93 million miles. Because Earth's orbital eccentricity — or the departure of its orbit from circularity — is a mere 0.017, its perihelion distance is approximately 0.986 AU (about 91.5 million miles) and its aphelion distance is approximately 1.017 AU (94.5 million miles.)

So, although there is indeed a slight difference between perihelion and aphelion distance, scientists believe that the greater amount of water in the Southern Hemisphere has a stabilizing influence on its climate and therefore compensates for any additional solar radiation that the Southern Hemisphere might receive. Also, Earth is close to perihelion — and therefore moving faster in its orbit — during the Southern Hemisphere's summer. This actually makes the southern summer shorter (88.99 days) than its northern counterpart (93.65 days).

Unlike Earth, some planets do experience significant temperature changes as a consequence of variations in their distance from the sun. When Pluto approaches its aphelion point, its temperature will be decreased to such an extent that its atmosphere will freeze and gather on the surface. — *Edward Gleason, Southworth Planetarium, Portland, Maine*

CONTACT INFO

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OPHIUCHUS

Summer splendors, such as globular clusters and planetary nebulae, dominate the Serpent-Bearer.

by Tom Polakis

AS THE COOL SPRING AIR GIVES way to summer's warm, balmy evenings, night skies provide great rewards for observers. The giant constellation Ophiuchus the Serpent-Bearer dominates the southern sky, providing dazzling views of globular clusters. No other constellation is so devoid of other objects, due to a halo of globular clusters that circles the galactic center, which lies just beyond the constellation's southwest border. Home to 25 of the 147 known globular clusters in the Milky Way Galaxy, only Sagittarius, with 31, contains more.

Ophiuchus is roughly house-shaped, with 2nd-magnitude Rasalhague gleaming at the tip of the roof. Just southeast, a finger of the Milky Way sometimes referred to as "The Offramp" dies at a V-shaped asterism called the "Bull of Poniatowski." This small group of 4th-magnitude stars proves useful in locating several telescopic targets. But the southern reaches of Ophiuchus hold the most interest for the majority of stargazers, where the Milky Way's band is at its widest and most detailed. A dark cloud of intervening material appropriately named the Pipe Nebula stands out as viewed from dark sites. On the best nights, this feature creates the hind legs of the larger "Dark Horse" Nebula.

We begin our telescopic tour with the bright globular cluster **M107** (NGC 6171), one of the objects in the Messier catalog discovered by Pierre Méchain. Lying near the galaxy's center at 20,000 light-years, its classification as one of the galaxy's disk or halo clusters remains uncertain. Through the smallest telescopes, M107 appears much like a distant comet, a haze with little concentration to the center. A good 8-inch scope begins to reveal the brightest stars in M107, which glow at magnitude 13, while medium apertures bring out several dozen stars across a luminous background.

In the center of the constellation shine two globulars that are rarely observed independently, **M12** (NGC 6218) and **M10** (NGC 6254). The two clusters have similar vital statistics, but leave slightly different impressions. Nearly physical twins, M12 and M10 each lie about 14,000 light-years away and are similarly spaced from the galaxy's center. Past astronomers have dated them at 17 billion years, paradoxically older than current estimates of the age of the universe. Intervening dust dims light from their stars by about 0.8 magnitude.

In a 10-inch telescope, M12 appears about 7' across, and is well-resolved into hundreds of stars. The stars at the center show little concentration, and the outer edge has a somewhat ragged appearance. Just a little over 3° to the southeast, M10 comes into view as a larger, more impressive cluster, showing member stars to a 10' diameter. It has a more well-defined center, along with a perfectly round edge.

Panning to the southern edge of Ophiuchus brings you to **M62** (NGC 6266). This cluster does not appear spherical through the eyepiece, owing to a fan of stars that extends from the northwestern edge. The integrated brightness of this cluster is similar to that of M12 and M10, but the stars are a magnitude fainter, making them *more difficult to resolve.* Yet the core appears very bright, packed densely with stars.

Artwork at left from *The Glorious Constellations*, copyright 1991, Harry N. Abrams, Inc.

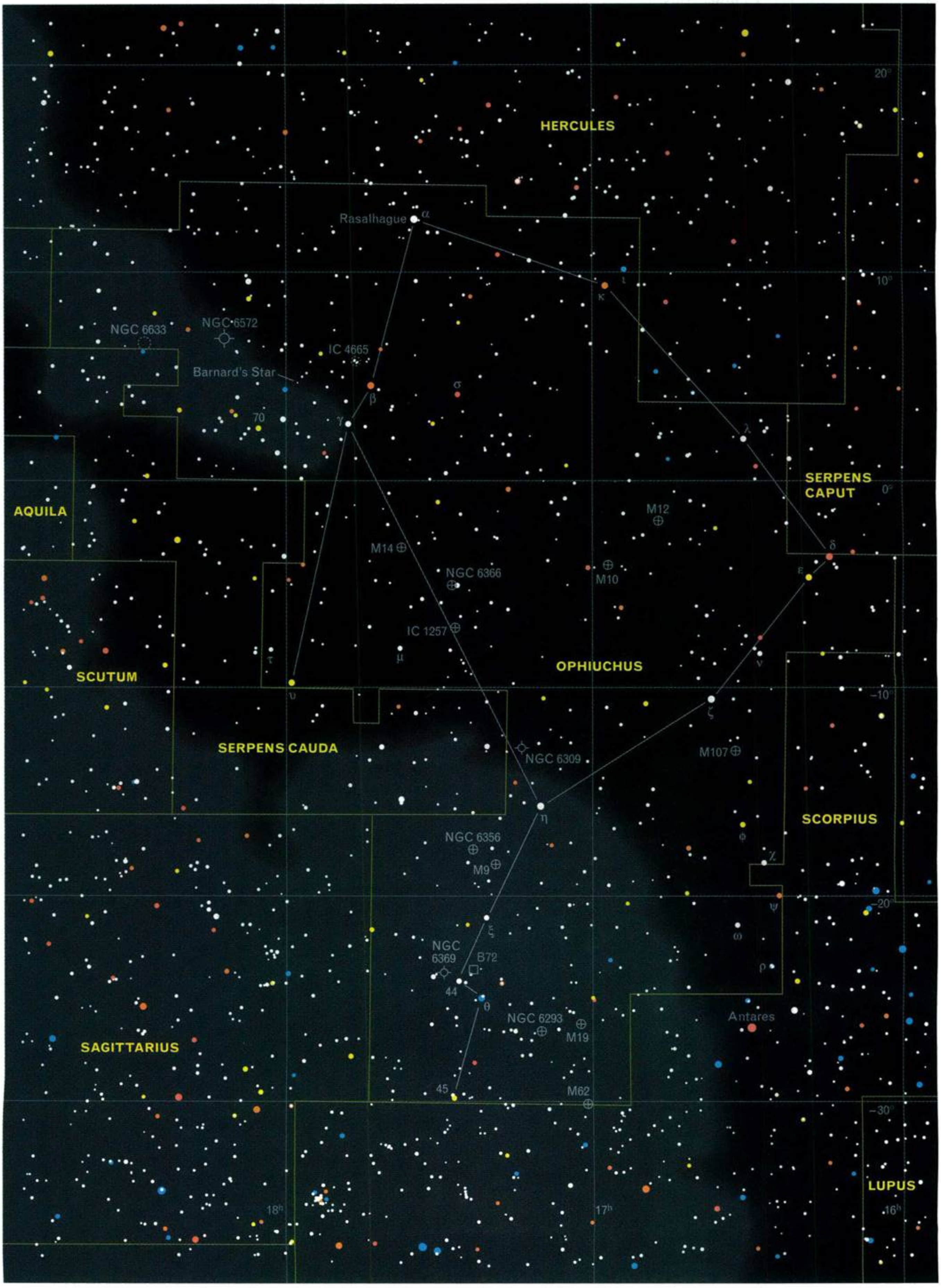
P. Scott and Mary Justis

Just 4° north lies **M19** (NGC 6273). Although all globular clusters exhibit some degree of oblateness due to rotation, M19 is considered the most flattened globular cluster in the Milky Way Galaxy. Astronomers previously believed that ellipticity was a real property of M19, but more recent investigations have shown that this is an illusion created by foreground absorption of starlight on its eastern and western edges. Positioned 33,000 light-years away and only 7,000 light-years from the galactic center, M19 shows an oval form visible in any telescope. An 8-inch scope has difficulty resolving more than a couple dozen stars across the cluster's face. The cluster becomes magnificent at a "critical aperture" of around 13 inches, above which it is transformed into a swarming mass of stars of nearly equal brightness. The oval aspect begins to diminish at higher magnifications.

Scan 2° east to find **NGC 6293**. After viewing the well-resolved globular clusters of the Messier catalog, we're brought back down to earth by one that's only "granular" in a 13-inch telescope. A view at high magnifications breaks the glowing ball into clumps of unresolved stars.

The planetary nebula **NGC 6369** presents a departure from the globular clusters that rule in Ophiuchus. Although this area in the bowl of the Pipe Nebula bears a striking absence of stars, the planetary's disk is only about 30" across, and takes magnification well. In a 10-inch at 200x, it appears as a perfectly circular ring with a brighter northern half. Larger scopes show a thin, brighter arc immersed in a ring that is otherwise uniform.

Now back off to your lowest magnification and pan a little over a degree to the west to find **Barnard 72**, the S Nebula. In photographs, the nebula seems inky black against a backdrop of multitudinous stars. Visually, these effects are much more subtle. My best views of the S Nebula have come not in large apertures, but in smaller, rich-field telescopes. Dark nebulae are one of the few classes of objects on which the rich-field telescope provides the best view. An 8-inch with an eyepiece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20°
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NGC 6572
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NGC 6366
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SERPENS CAUDA
NGC 6309
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SCORPIUS
NGC 6356
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NGC 6369
B72
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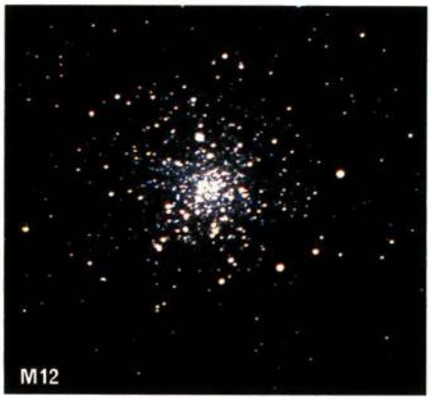
Antares
NGC 6293
M19
SAGITTARIUS
45
M62
-30°
LUPUS
18h
17h
16h

providing a 2° field shows the dark lane winding across a half degree, and terminating at a dark blob on the south end. The entire area surrounding the Pipe Nebula is outstanding for sweeping with this type of instrument.

Inside another dark nebula, **Barnard 64**, lies the small globular cluster **M9** (NGC 6333). Even through a 16-inch telescope, it measures only about 4' across despite its brightness. 14th-magnitude stars resolve well across the face of the globular. Several observers have commented on the triangular core that can be seen in underexposed images.

Sweep a little more than a degree northeast of M9 to find **NGC 6356.** Though easy to locate through a finderscope, its great distance makes it a challenge to resolve. A 16-inch telescope shows a peppering of very faint stars around the edge, but nothing more than a brightly concentrated center evades resolution. We learn from Brian Skiff's Globular Cluster Database (http://ngcic.com/gcdata.htm) that the brightest stars in NGC 6356 glow dimly at only magnitude 15.1, due to its remote location—50,000 light-years, or a full 26,000 light-years on the other side of the galaxy's center.



Bill Iburg

About 2° west of 4th magnitude Nu (ν) Serpentis is the small and bright planetary nebula **NGC 6309**, sometimes called the "Box Nebula." At low powers, the small disk measures about 15" by 10", elongated north-south. At a magnification of 300x, it presents a dumbbell form with a larger northern lobe. A 12th-magnitude star glows just off the northern edge.

At a distance of 30,000 light-years, the numerous faint stars in **M14** (NGC 6402) make it a circular version of M19. It is easily acquired through a finderscope, but defies resolution up to a certain aperture. Above this aperture, hundreds of faint stars become dazzlingly visible. A 13-inch telescope at a dark site only begins to resolve stars at the outer edge. Through a 20-inch, though, scores of faint gems dot the field, uniformly placed across a central glowing sphere with no noticeable concentration. In their *Observing Handbook and Catalogue of Deep-Sky Objects*, Chris Luginbuhl and Brian Skiff notice some granularity in a 6-inch refractor at high power. In a 12.5-inch instrument, they still find it poorly resolved for so bright an object.

While the overall light of **NGC 6366** is two magnitudes fainter than M14, its stars resolve more easily. This sparse globular cluster, located at a distance of 9,000 light-years, emerges as a small and faint open cluster in a large telescope. A couple dozen of its brightest stars are visible with little background glow in a 13-inch scope.

Scan 2° due south to find **IC 1257.** Discovered in 1890, it was classified as an open cluster until 1997, when a

Deep-Sky Objects in Ophiuchus

Object	**R. A. (2000.0)**	**Dec.**	**Mag.**	**Size/Sep./Per.**	**Type**	**Notes**
M107 (NGC 6171)	16h32.5m	–13°03'	8.5	10'	GC	
M12 (NGC 6218)	16h47.2m	–1°57'	6.8	14.5'	GC	
M10 (NGC 6254)	16h57.1m	–4°06'	6.6	15.1'	GC	
M62 (NGC 6266)	17h01.2m	–30°07'	6.7	14.1'	GC	
M19 (NGC 6273)	17h02.6m	–26°16'	6.7	13.5'	GC	
NGC 6293	17h10.2m	–26°35'	8.2	7.9'	GC	
NGC 6369	17h29.3m	–23°46'	11.4	>30"	PN	
B72	17h23.5m	–23°38'	—	4'	DN	Snake Nebula
M9 (NGC 6333)	17h19.2m	–18°31'	7.6	9.3'	GC	
NGC 6356	17h23.6m	–17°49'	8.2	7.2'	GC	
NGC 6309	17h14.1m	–12°55'	11.5	>16"	PN	Little Ghost
M14 (NGC 6402)	17h37.6m	–3°15'	7.6	11.7'	GC	
NGC 6366	17h27.7m	–5°05'	8.9	8.3'	GC	
IC 1257	17h27.1m	–7°04'	—	2.0'	GC	
IC 4665	17h46.3m	5°43'	4.2	40'	OC	
Barnard's Star	17h57.8m	4°42'	9.5	—	Star	Proper Motion = 10.3"/year
70 Oph	18h05.5m	2°30'	4.3/6.0	3.5"	Dbl	
NGC 6572	18h12.1m	6°51'	8.1	8"	PN	
NGC 6633	18h27.7m	6°34'	4.6	27'	OC	

Object: Designation in Messier, NGC, or other catalog. **R.A. (2000.0) and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size/Sep./ Per.:** Size in arcminutes or arcseconds, separation in arcseconds, or period in days. **Notes:** Hubble type for galaxies or type for variable stars.

The Serpent-Bearer

"Alas I find the Serpent old
That, twining in his speckled breast
About the flow'rs disguis'd does fold
With wreaths of Fame and Interest."
The Coronet
Andrew Marvell (1621-1678)

Many constellations represent bizarre mythological stories, tales of betrayal and unrequited love that often somehow find a happy ending. Ophiuchus the Serpent-Bearer is no exception. Seen in the nighttime sky as a man holding a huge snake in his hands, the Serpent-Bearer stands for, ironically, health and healing. Ancient people believed that the serpent was reborn each spring as it shed its skin, making it a symbol of renewal.

The myth revolves around the god of healing or medicine, Asclepius, the son of Apollo and Coronis. His mother had an affair with a mortal while pregnant. Upon discovering his lover's unfaithfulness, Apollo ordered his sister Artemis to slay Coronis, but rescued his infant son Asclepius from his mother's womb in the nick of time. Apollo then delivered his son to the wise centaur Chiron and asked him to raise the innocent child.

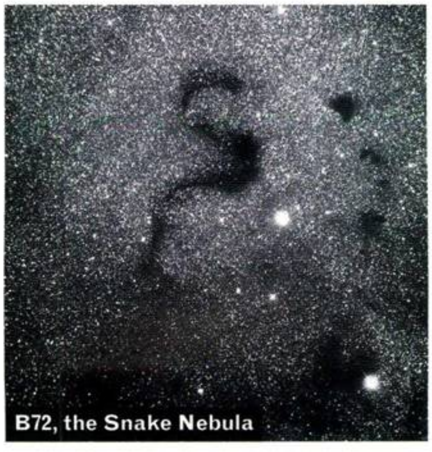
While in Chiron's care, Asclepius somehow gained the power to restore life with an herb used by a serpent. Thrilled by this gift, he saved so many people from death that Hades, the God of the Underworld, complained that he would soon have no subjects to rule over. In response, his brother Zeus struck down the enthusiastic Asclepius with a thunderbolt, causing the outraged Apollo to seek revenge. So to appease him, Zeus immortalized Asclepius, setting him in the sky eternally as the constellation Ophiuchus the Serpent-Bearer. —*Elesa Janke*

collaboration of the amateur and professional communities brought it into recognition as a globular cluster. CCD photometry with the 5-meter Hale Telescope on Palomar Mountain shows it as a very distant globular, lying 78,000 light-years away, and 52,000 light-years beyond the galactic center. The dust between us and IC 1257 acts to dim the cluster by 2.4 magnitudes; a minimum aperture of 10 inches is probably required to detect its exceedingly faint glow. IC 1257 appears as no more than an unresolved haze 1' across.

Simply a pair of binoculars provides a good view of the wide-open cluster **IC 4665.** Aim a pair of 7x50mm binoculars to see a dozen stars scattered widely over one degree. Arizona observer Steve Coe notes that the cluster is visible to the naked eye at dark sites.

Those interested in a long-term project should take a look at **Barnard's Star**, and make a note of its current position. This is the "Runaway Star," so named for its proper motion, which is the highest of any star. Barnard's Star moves nearly due north by 10.3" each year; skilled observers may be able to notice its motion over the course of one observing season. At a scant distance of 5.9 light-years, this red dwarf shines feebly; the sun is nearly 3,000 times as luminous. It is visible in a 60mm refractor as a 9.5 magnitude star, near a small V-shaped asterism.

Another object well-suited for a project that may take a few years is 4th-magnitude **70 Ophiuchi**, one of the stars of the Bull of Poniatowski. Like Barnard's star, it is far from static. One of the closest binary stars, it has a short orbital period, and the orbital motion can be observed over a very short time span. The 6th-magnitude companion has made more than two 88-year circuits since its discovery in the 18th century. Currently the two stars are separated by an easily resolvable 3.5" but are opening rapidly. In ten years, they will be split by 5.6" on their way to a maximum of 6.8", to be attained in 2024. The physical separation of the two components of 70 Ophiuchi ranges from only 11.7 to 35 astronomical units, with a current separation similar to Earth's distance to Uranus.



B72, the Snake Nebula

Michael Stecker

Scanning 4.6° north of 70 Ophiuchi brings us to the colorful planetary nebula **NGC 6572.** Its diminutive size of only 10" prevents much detail from being visible, but it appears bright and invites high magnification. Recent measurements date the cluster at 1,000 years old and place it at a distance of 4,000 light-years. In an 8-inch, NGC 6572 shows an oval form and a brighter center. Its bright green color proves the most impressive aspect of the view, becoming more apparent at low magnifications. The spectral lines of this planetary vary in intensity — an effect that is likely due to changes in the temperature of the central star.

Our tour concludes in northern Ophiuchus, well out of the realm of globular clusters, where other classes of objects, such as open clusters, become available. **NGC 6633** is another grouping that turns up nicely in the finderscope. At a distance of 1,000 light-years, it contains 15 stars brighter than 10th magnitude and an additional 50 fainter stars across an area nearly 1° across. A high-resolution telescope, like a small refractor, offers the most impressive view. ■

Tom Polakis is an aerospace engineer living in Tempe, Arizona, whose favorite astronomical pursuits are deep-sky observing and photography.

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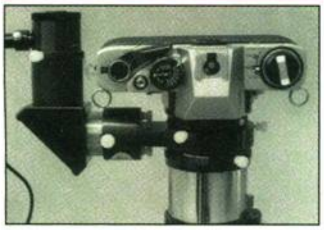

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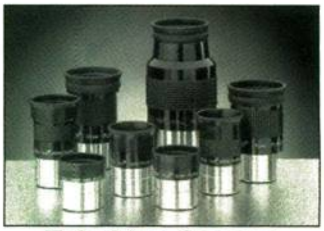

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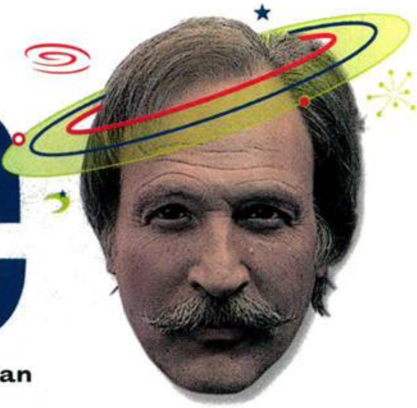

by Bob Berman

Close Call from a Bad-Luck Planet

Mars has always intrigued. The ancients started the ball rolling by noticing that only one "wandering star" had a truly vivid color. Alarmingly, it was reddish. Back then, many cultures were quicker to link red with blood than with herrings. They also believed such moving lights were gods, and a red god was not presumed to be a happy camper; a ruddy divinity was more likely inflamed with rage than simple sunburn.

Then, too, Mars moved the fastest of all the out-at-midnight worlds, and changed in brightness more than any other. Every 26 months, its brilliance would ratchet up dramatically, but it would brighten differently each time. This was strange, and strange was not good.

Interest in this planet never has waned through the centuries. A hundred years ago Mars often made front-page news, especially when astronomers like Percival Lowell said they thought it might have intelligent life. The idea really took off when canals were mistakenly observed there, but now we know the whole thing was largely a linguistic mistake. "Canals" was how English-speaking newspapers translated the word used by the famous observer Schiaparelli. He may have called them "canoli," thinking wishfully that he was viewing long rows of Italian pastry. But no, what he really said was "canali," which means channels. Nothing was artificial about the channels, but the damage was done and the life-on-Mars fever never fully subsided after that.

The delirium probably peaked with H.G. Wells's novel, *War of the Worlds*, and the hysteria-producing radio script written by Howard Koch and read by Orson Welles. For the science community, the high water mark may have been the now-infamous NASA press conference of 1996. With a straight face, Administrator Dan Goldin introduced a team of experts who essentially told reporters that they had discovered life on Mars. Germ-sized, fossilized imprints of life to be sure, but life nonetheless.

This incident shows how wrong the movies are. You know the typical scene where an army general warns his staff the public "must never be told about the discovery of life beyond Earth: People will panic!" Later in the film, the public does learn about the aliens, and people stampede wildly through the streets. I always wondered about that. Would our seriously overweight citizenry really dash around so energetically? And where would they go to elude space creatures? I think everyone would just grab the phone to be the first to tell friends.

Anyway, we found out what the public would do. You'll recall that the actual reaction to NASA's life-on-Mars announcement was about as animated as last year's vice-presidential debate. It did, however, create a controversy that provides yet another excuse to go there and find out once and for all.

Alas, going there has been a problem. Mars has proven to be a bad- luck destination. Consider: We launch four spacecraft to Saturn and they all work beautifully. We're five-for-five with Jupiter and one-for-one with Mercury. But for reasons no one can explain, Mars — closer and potentially easier to reach — has been nothing but trouble. Of the 29 spacecraft sent there, 18 have exploded, crashed, or malfunctioned. The abysmal 11-for-29 success rate has made some paranoid people even more so; they suspect malevolent aliens who do not like our snooping.

I'd go along with that spooky idea if all the craft had failed. But the "see-the-donut-not-the-hole" viewpoint is that some of the most important missions have been wildly successful. The twin Vikings hit home runs in 1976, and in 1996 more runs were scored with the Pathfinder lander, Sojourner rover, and the orbiting Global Surveyor. If martians are trying to stop us, they've not been particularly competent, and that makes all the difference in how we'll perceive them. Incompetence is a quality we're familiar and comfortable with. Incompetent aliens might be weird but they can't be too menacing; they remind us of our in-laws.

We're giving the aliens another chance. April brought the scheduled launch of the newest try-to-reach-Mars probe, bearing the NASA-likes-movies designation, "2001 Mars Odyssey." If it arrives on schedule in October, its three orbiting instruments will survey the terrain looking for minerals and such. It also carries a device called MARIE, an almost-anagram for Mars Radiation Environment Experiment. MARIE will assess the radiation hazard of letting humans orbit Mars, a good idea given the region's lack of primary care physicians.

Mars doesn't just bring bad luck, it's had nothing but.

Situated just inside the asteroid belt, it was clobbered mercilessly during the solar system's violent wild-west era. During that period, which ended suddenly and mysteriously

3.9 billion years ago, meteors of all sizes pummeled everything. (That's when Earth was battered by something so big it broke off a chunk large enough to create the moon.) Mars fared worst of all planets then, which is why its surface is an unending sea of debris.

To date, some 13 meteorites found on Earth have been identified as having come from Mars. Our worlds have indeed been physically linked. If microscopic life somehow formed there first, it may well have been hurled away by an impact, and could easily have landed here to "seed" our planet. In which case, we're all martians.

Certainly we seem to have a Mars obsession. Some of us share dreams and plans that will take us there someday. These are almost palpable. Meanwhile we're immersed in martian sci-fi movies, what's-under-its-surface science intrigue, even bizarre curiosities. Is it not strange that Jonathan Swift wrote fictionally in *Gulliver's Travels* that Mars has "two moons" and attributed to them distances and orbital periods that closely match the real Phobos and Deimos discovered 150 years later? Isn't it odd that the ruddy tint of the martian soil is due to iron, which is just what colors our red blood cells, completing the ancient Mars/blood association? And why does that planet alone share its name with a candy bar?

The attraction goes on. Perhaps that's why this month, as Mars pays its nearest visit to us since 1988, we're so drawn to that brilliant, strongly tinted "star" out all night in the southern sky. As if the planet were trying to entice us even more, the day of Mars's closest approach is the same day as summer solstice and the first solar eclipse of the new millennium.

We're not superstitious but we enjoy associations: That's what made Mars so intriguing in the first place. We're quick to notice celestial chords and rhythms, and it doesn't matter if they've been fashioned by nothing more than coincidence. This month's Mars-solstice -eclipse triad might have had primitive cultures banging drums or building pyramids. Now we look up and savor it, even if our zoning ordinances discourage the exuberance of human sacrifice.

Bob Berman writes regularly for Astronomy *magazine and is the author of several books, including* Secrets of the Night Sky.

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PRODUCTS

NexStar 11 GPS

Amateur astronomers can now buy a smart telescope that takes advantage of the U.S. Department of Defense's fleet of 24 Global Positioning System (GPS) satellites. Celestron's NexStar 11 GPS uses the satellite signals to determine precise ground location, date, and time. It also uses an on-board compass to align itself directly north, and an internal device levels the optical tube. Because the telescope does much of the work for its user, setting up this 65-pound, 11-inch f/10 Schmidt-Cassegrain telescope (SCT) is surprisingly simple and automatic.

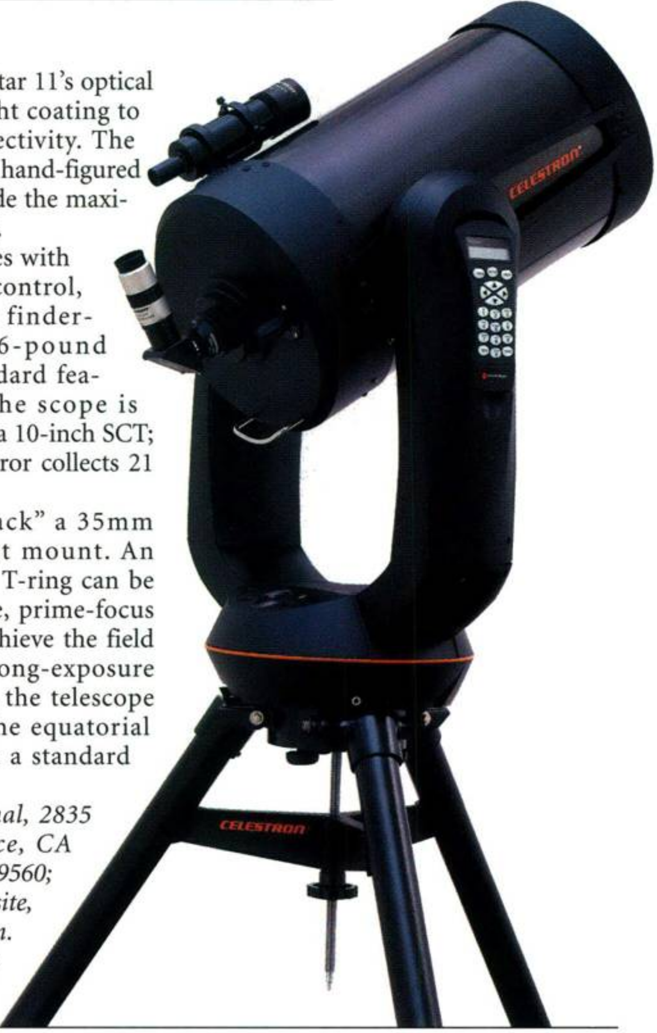
The telescope can be used manually or guided automatically, and its computer database contains about 40,000 astronomical objects. Sky surfers can store the coordinates of their favorite objects in the database and the telescope can return to them on other nights from new observing locations.

The NexStar 11 also features a carbon-fiber optical tube, which is lightweight, durable, and has lower thermal-expansion properties than tubes made with aluminum or other metals. Each of the NexStar 11's optical elements has a Starbright coating to provide maximum reflectivity. The optical elements also are hand-figured and guaranteed to provide the maximum resolution possible.

The NexStar 11 comes with a computerized hand control, AC adapter, 9x50mm finderscope, heavy-duty 26-pound tripod, and other standard features and options. The scope is roughly the same size as a 10-inch SCT; however, its 11-inch mirror collects 21 percent more light.

Users can "piggyback" a 35mm camera with a bracket mount. An optional T-adapter and T-ring can be used for short-exposure, prime-focus astrophotography. To achieve the field derotation needed in long-exposure deep-sky photography, the telescope must be operated in the equatorial mode and mounted on a standard equatorial wedge.

Celestron International, 2835 Columbia St., Torrance, CA 90503; phone, (310) 328-9560; fax, (310) 212-5835; website, http://www.celestron.com. $2,995 (plus shipping and handling).



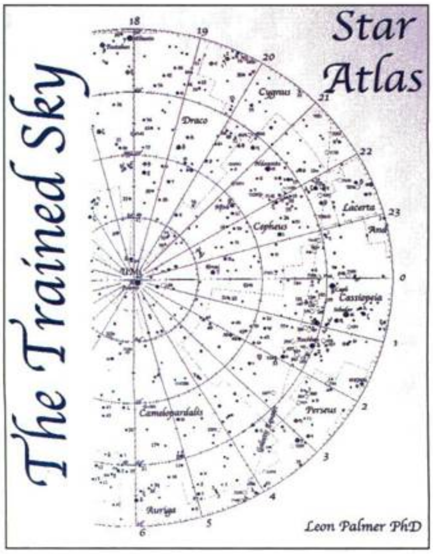
StarDust

Manufacturers of eyepieces ship them in handy cases, but most telescope users tend to misplace them. This nettlesome problem led amateur astronomer William Falcone to develop his StarDust line of molded-polypropylene containers. StarDust containers have polyethylene-foam inserts for a better fit to protect eyepieces. The cases also can be used for a variety of telescope accessories, including CCD cameras, Barlow lenses, focal reducers, laser collimators, coma correctors, filters, and other items.

Absolute Astronomy, 21 High St., Noank, CT 06340; phone, (860) 536-6002; e-mail, opti@optiguy.com, website, http://www.optiguy.com. $2.25 to $6 each (plus shipping and handling).

The Trained Sky

The 11" by 17" maps in *The Trained Sky* star atlas are printed on coated paper for moisture resistance and durability. Each map covers sections of the sky that are large enough for users to see the relationships between constellations with minimal visual distortion. Stars (black disks on a white background) as faint as 6th magnitude are plotted along with hundreds of other objects. The atlas also includes helpful tables on the brightest stars, multiple stars, Messier objects, and constellations.



Rigel Systems, 26850 Basswood Ave., Rancho Palos Verdes, CA 90275; phone, (310) 375-4149; website, http://www.rigelsys.com. $9.95 (plus $2.95 shipping).

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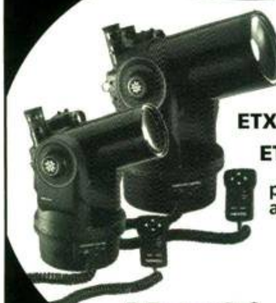

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A BOOKS

Atom: An Odyssey from the Big Bang to Life on Earth ... and Beyond

Lawrence M. Krauss, 320 pages, Little, Brown and Company, New York, 2001; ISBN 0-316-49946-3; hardcover, $26.95.

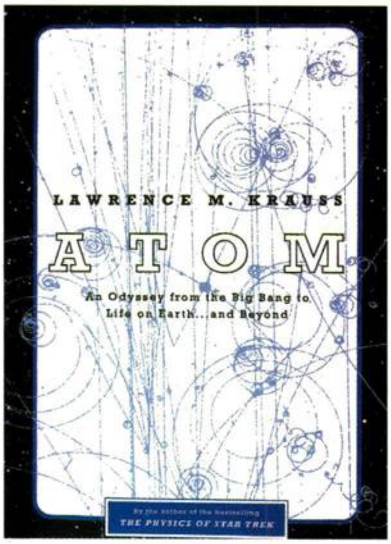
The late Carl Sagan coined the phrase, "We are made of star stuff." The premise of this claim is that all but the smallest atoms in each living creature on Earth were formed in stars. Krauss, a physics professor at Case Western Reserve University in Cleveland, Ohio, takes this as the theme of his book, *Atom: An Odyssey From the Big Bang to Life on Earth ... and Beyond*. The author, who also wrote *The Physics of Star Trek*, follows the history of the cosmos — and humanity — from the perspective of an oxygen atom.

This latest book reminds me of Carl Sagan's *Cosmos*, the best-selling science book ever published in the English language. *Atom* begins, logically, with the creation of the universe and explains how the slight lumpiness of the early universe had fortunate consequences for us. Krauss then examines the birth and evolution of the first generations of stars, concluding with the birth of the sun, the planets, and the rise of microscopic life on Earth. The final section chronicles the evolution of complex life on Earth and its fate. The journey ends with a discussion of the implications of recent cosmological findings on the fate of the universe; competing groups of astronomers have found evidence that its expansion rate is accelerating.

Krauss employs a whole array of science — physics, chemistry, geology, biology, and anthropology — to tell his story. He elaborates on particle physics, matter-antimatter asymmetry, time-reversal symmetry, quantum mechanics, string theory, stellar evolution, hydrostatic equilibrium, and thermodynamics. Throughout, he examines the creation of our universe, solar system, ecosystem — and us. His philosophical forays lead him to discuss a creator deity.

While a number of *Cosmos* knockoffs recently have appeared, *Atom* gives us a different perspective, one that is more comprehensive in scope. Krauss repeats important themes and uses familiar examples to explain complex concepts. When the story of his main character — the life-giving oxygen atom — begins to drag, the author enlivens it with interesting digressions on related topics.

I was disappointed that this challenging book doesn't have illustrations to help readers understand the story. However, Krauss's lucid style helps make up for the lack of visuals. PBS, which produced the first science-miniseries blockbuster *Cosmos*, is planning a series based on *Atom*, but read the book first. *Atom* is a must for anyone who has ever looked up at the billions and billions of stars in the heavens and wondered not only how it all came to be, but also how it may end. — *Jennifer Birriel, Carleton College, Northfield, Minnesota*


LAWRENCE M. KRAUSS
ATOM
An Odyssey from the Big Bang to Life on Earth...and Beyond
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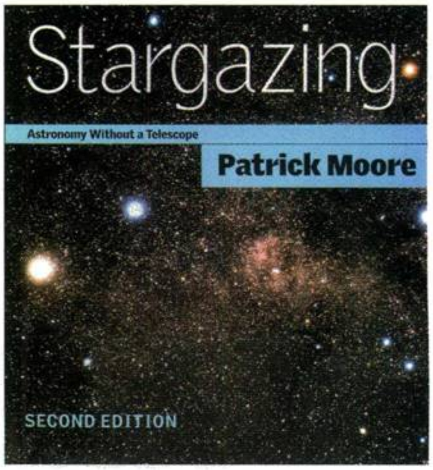
THE PHYSICS OF STAR TREK

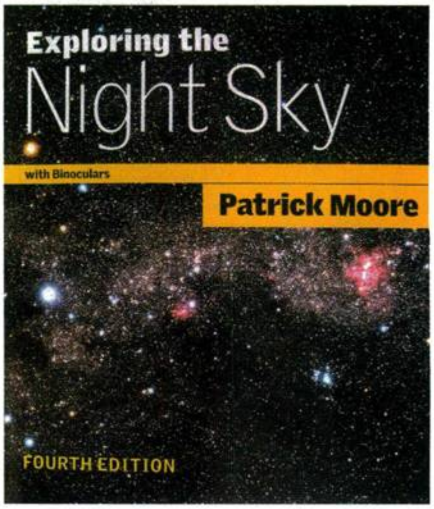
Stargazing: Astronomy without a Telescope, 2nd edition

Patrick Moore, 209 pages, Cambridge University Press, New York, 2000; ISBN 0-521-79052-2; hardcover, $32.95; ISBN 0-521-79445-5; paperback, $18.95.

Exploring the Night Sky with Binoculars, 4th edition

Patrick Moore, 213 pages, Cambridge University Press, New York, 2000; ISBN 0-521-79053-0; hardcover, $32.95; ISBN 0-521-79390-4; paperback, $18.95.





While these two books might appear very similar, they serve two types of beginning observers. Identifying constellations is challenging for beginners, and even professional astronomers can have trouble picking out Camelopardalis or Lacerta. Moore's *Stargazing: Astronomy without a Telescope* is a great basic astronomy book that is so reader-friendly even novices can use it to quickly point out the constellations.

In *Stargazing*, Moore briefly explains how the visible universe appears to an observer on the ground, and offers practical information that helps the observer learn how to locate particular stars.

Likewise, *Exploring the Night Sky with Binoculars* is the perfect guide for people who want a better view. Building on *Stargazing*, Moore uses *Exploring* to lead the binocular user through stars, clusters, nebulae, and galaxies.

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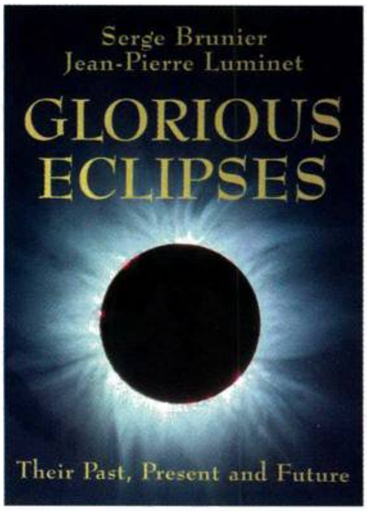
Each of these guides contains plenty of observing tips, constellation maps, and tidbits of astronomical history and legends. Diagrams clearly illustrate the text whenever necessary. Both provide a solid foundation for anyone who wants to proceed from mere interest, to naked-eye viewing, to binocular observing and beyond. — *Carol Ryback, associate editor*

Glorious Eclipses: Their Past, Present and Future

Serge Brunier and Jean-Pierre Luminet, 192 pages, Cambridge University Press, New York, 2001; ISBN 0-521-79148-0; hardcover, $39.95.

Unique human and scientific stories lie in the shadow of each eclipse. Brunier and Luminet bring them to light in *Glorious Eclipses*. It's full of enough photographs, drawings, and paintings to entice first-time eclipse watchers and satisfy the aficionados of umbras and penumbras. Originally published in French by photojournalist Brunier and astronomy researcher Luminet, the book loses little in this skillful translation by Storm Dunlop.

Don't expect groundbreaking scientific discussions. Instead, readers will enjoy historical sketches that emphasize the human aspect of eclipses and eclipse watching. Eclipses — particularly total solar eclipses — become emotional events that transcend the physics of syzygy, when the sun, moon, and Earth lie approximately in line.



Seven engrossing chapters explore the many wonders of these cosmic phenomena. The glossary and index help readers navigate the book as quickly as they roam the night sky. The last third of the book, which shows when and where to observe lunar and solar eclipses, includes maps of the paths of solar eclipses through the year 2060. That should be enough to keep most eclipse chasers occupied until the next edition. — *C. R.*

The Cambridge Astronomy Dictionary

Jacqueline Mitton, 400 pages, Cambridge University Press, New York, 2001; ISBN 0-521-180045-5, hardcover, $52.95; ISBN 0-521-180480-9, paperback, $18.95.

The astronomy reference work I consult most often is Jacqueline Mitton's 1991 guide, *A Concise Dictionary of Astronomy*. I'll call it *Mitton I*. Now, a new star eclipses that cherished book (although this usage is contrary to Mitton's authoritative definition of "eclipse"). *The Cambridge Astronomy Dictionary*, what I call *Mitton II*, is as good as *Mitton I* and more up-to-date.

Mitton II has at least 600 additional entries, despite some pruning. (For example, entries like "Crow" and "Cup" — the English names for constellations Corvus and Crater — were dropped.) Entries have been added on new and future facilities, such as "KUEYEN" (one of four main reflectors in the European Southern Observatory's Very Large Telescope), the "Hobby-Eberly Telescope," and the "Atacama Large Millimeter Array." New science terms and provisional ones that have grown in usage are now incorporated. Mitton gives us "magnetar," "Kuiper Belt," and, for purists, the "Edgeworth-Kuiper Belt."

Another new term is "Plutino," a small body that, like Pluto, makes two revolutions around the sun for every three revolutions of Neptune. This 2:3 resonance ensures that neither Pluto nor the Plutinos come close enough to Neptune to be significantly affected by its gravitational attraction. I'm glad this authoritative dictionary begins a long entry on Pluto with, "The ninth planet of the solar system." With the International Astronomical Union and *Mitton II* on Pluto's side, it may be protected from the astronomers who would demote it to minor-planet status.

"Gamma-ray burster" has been replaced by a longer entry on "gamma-ray burst," which includes the recently discovered GRB afterglows. For *Mitton III*, we'll expect even more science entries, as terms like LSB (low surface brightness) galaxy and "hot Jupiter" (a Jupiter-class planet in orbit very close to its parent star) come into common parlance. Phenomena discovered since *Mitton II* was published, such as the Earth's sunward-pointing plasma tail, are sure to be added, too. — *Stephen P. Maran, Space Sciences Directorate, NASA's Goddard Space Flight Center, Greenbelt, Maryland*

The Webweaver Picks

StarDome

The Auckland Observatory's site is a helpful website not only for New Zealanders, but for any southern-sky observer looking for sky events and news.
http://www.stardome.org.nz/

Hubble Space Telescope

An exhibition of the Hubble Space Telescope is touring the United States. If you can't get to it, there's an online companion.
http://hstexhibit.stsci.edu/

NASA/IPAC Extragalactic Database (NED)

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http://nedwww.ipac.caltech.edu/index.html

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www.swin.edu.au/astronomy

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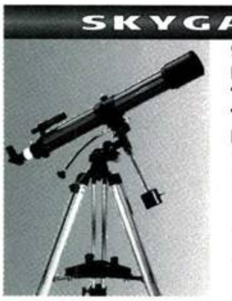

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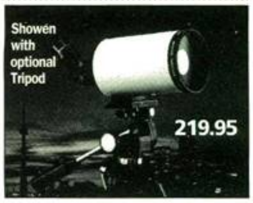

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JUNE 3–7

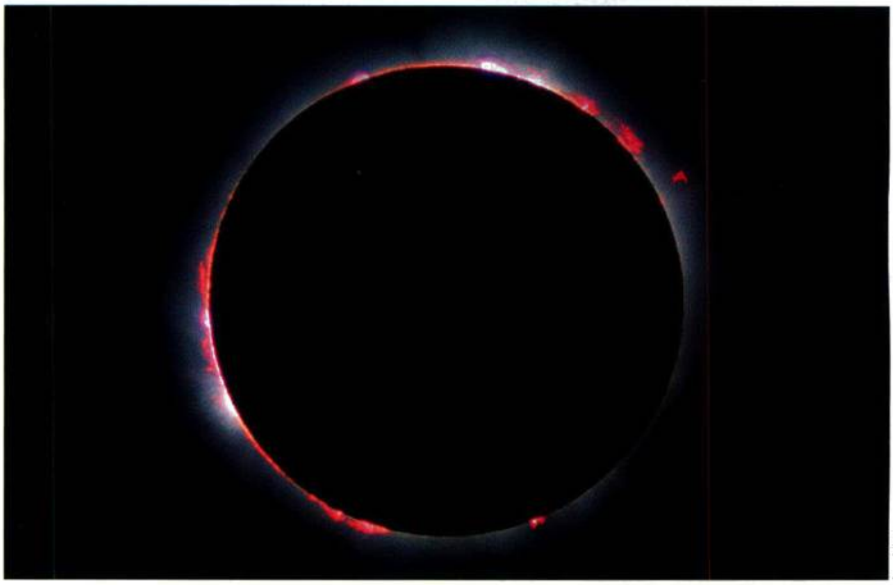
American Astronomical Society Annual Meeting

Pasadena Center, Pasadena, California. Direct correspondence to: AAS 198th Meeting, American Astronomical Society, 2000 Florida Ave. NW, Suite 400, Washington, DC 20009-1231; (202) 328–2010; e-mail, aas@aas.org; website, http://www.aas.org.

JUNE 5–12; 15–23; 25–28

Astronomy Camps for Teenagers and Educators

Mt. Lemmon and Mt. Bigelow Observatories, University of Arizona, Tucson, Arizona. Beginner teens, June 5–12; advanced teens, June 15–23; educators, June 25–28. Contact Don McCarthy, 933 North Cherry Avenue, Tucson, AZ 85721-0065; (520) 621–4079; e-mail, dmccarthy@as.arizona.edu; website, http://ethel.as.arizona.edu/astrocamp.



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A total solar eclipse will be visible from Africa on June 21, 2001.

JUNE 14–17

Laurel Highlands Star Cruise

Pine Hill Campground, near Hazelton, West Virginia. For more information, contact John Holtz, (724) 352–7596; e-mail, jwholtz@aol.com or Mary Jean Kancel, (412) 859–5732; e-mail, kancel@attglobal.net; website, http://www.members.home.net/lhstarcruise.

JUNE 15–17

Wisconsin Observers Weekend

Hartman Creek State Park, west of Waupaca, Wisconsin. Sponsored by the Northeast Wisconsin Stargazers. Contact Terry Becker at (920) 426–2286 or email, tlb@vbe.com; website, http://www.new-str.org.

JUNE 16–23

Grand Canyon Star Party

North and south rims of Grand Canyon National Park, Arizona. Sponsored by the National Park Service and the Tucson Amateur Astronomy Association. Contact Dean Ketelson, (520) 293–2855; e-mail, ketelsen@as.arizona.edu;website,http://www.tucsonastronomy.org/gcsp.html.

JUNE 15–16

Apollo Rendezvous and Telescope Fair

Boonshoft Museum of Discovery, Dayton, Ohio. Hosted by the Miami Valley Astronomical Society. Contact AR2001, 2600 Deweese Pkwy, Dayton, OH 45414; e-mail, mvas@mvas.org; website, http://www.mvas.org.

JUNE 21

Canyonlands Needles Outpost Summer Solstice Star Amazement Party

Canyonlands National Park, Utah. For further information, contact (435) 979–4007; e-mail, cno@sanJuan.net; website, http://www.canyonlandsneedlesoutpost.com.

JUNE 21–24

Rocky Mountain Star Stare

Wolf's Run, Pike National Forest, Colorado. Sponsored by the Colorado Springs Astronomical Society. Pre-registration is required. Contact Chris Earley, (719) 567–8292; e-mail, chrisearley@sprynet.com; website, http://www.rmss.org/rmss2001.htm.

JUNE 22–23

Greater Verde Valley Astronomy Festival

Red Rock State Park, near Sedona, Arizona. Sponsored by the Verde Valley Astro Club and Sirius Lookers Club.

Contact Rick Shaffer, (520) 204–2716; e-mail, rickshaf@earthlink.net or Russel Nidey, 1101 Zalesky Road, Bridgeport, AZ 86326; (520) 634–7332; e-mail, astroctr@wildapache.net.

JUNE 22–24

Craters of the Moon Star Party

Craters of the Moon National Monument, near Arco, Idaho. Sponsored by the Idaho Falls Astronomical Society and the Magic Valley Astronomical Society. Contact Jay Sneddon, (208) 736–2447; website, http://www.mvas.net/members/Craters_of_the_Moon/index.html.

JUNE 22–24

Jersey StarQuest

Hope Conference and Renewal Center, Hope, New Jersey. Contact Greg Mauro, 915 Princess Drive, Yardley, PA 19067; e-mail, k3ea@arrl.net.

JUNE 23–25

Mason-Dixon Star Party

Spring Valley County Park, near York, Pennsylvania. Sponsored by the York County Astronomical Society and the York County Parks. Contact Jeri Jones, York County Parks, 400 Mundis Race Road, York, PA 17402; (717) 840–7226; e-mail, jlj276@aol.com; website, http://home1.gte.net/dmdewey/mdsp.html.

JUNE 26–30

Great Lakes Planetarium Association Conference

Hummel Planetarium, Eastern Kentucky University, Richmond, Kentucky. Joint meeting with the Southeastern Planetarium Association. Contact Jack Fletcher at (859) 622–1547; email, hplfletc@acs.eku.edu; website, http://www.pa.msu.edu/abrams/glpa.html.

JUNE 29–JULY 1

2001: A Space RASC Astronomy Convention

London, Ontario, Canada. Hosted by the London Centre of the RAS. For information, e-mail, ga2001@rasc.ca; website, http://www.rasc.ca/ga2001. A

CONTACT

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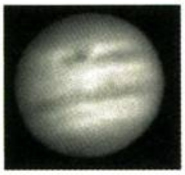

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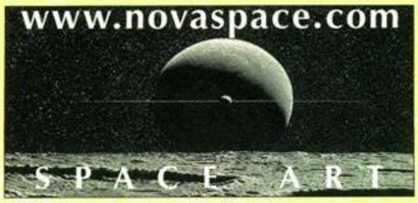

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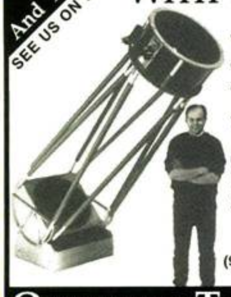

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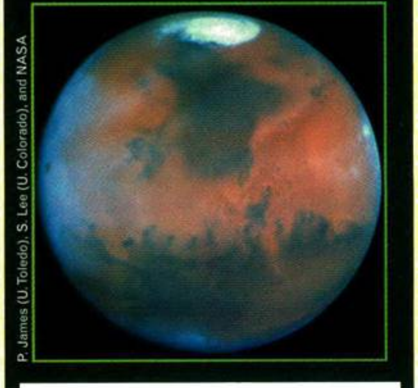

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- Special Star Party on Friday, July 13 hosted by the Minnesota Astronomical Society
- "Universe in the Classroom 2001," a workshop for grade 3-12 teachers, July 16-17
- "The High-Energy Universe at Sharp Focus: Chandra Science," a science symposium for professional astronomers, July 16-18

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Image courtesy of the European Southern Observatory

HOT SHOTS

A collection of your images and observations

ASTRO ADVENTURES

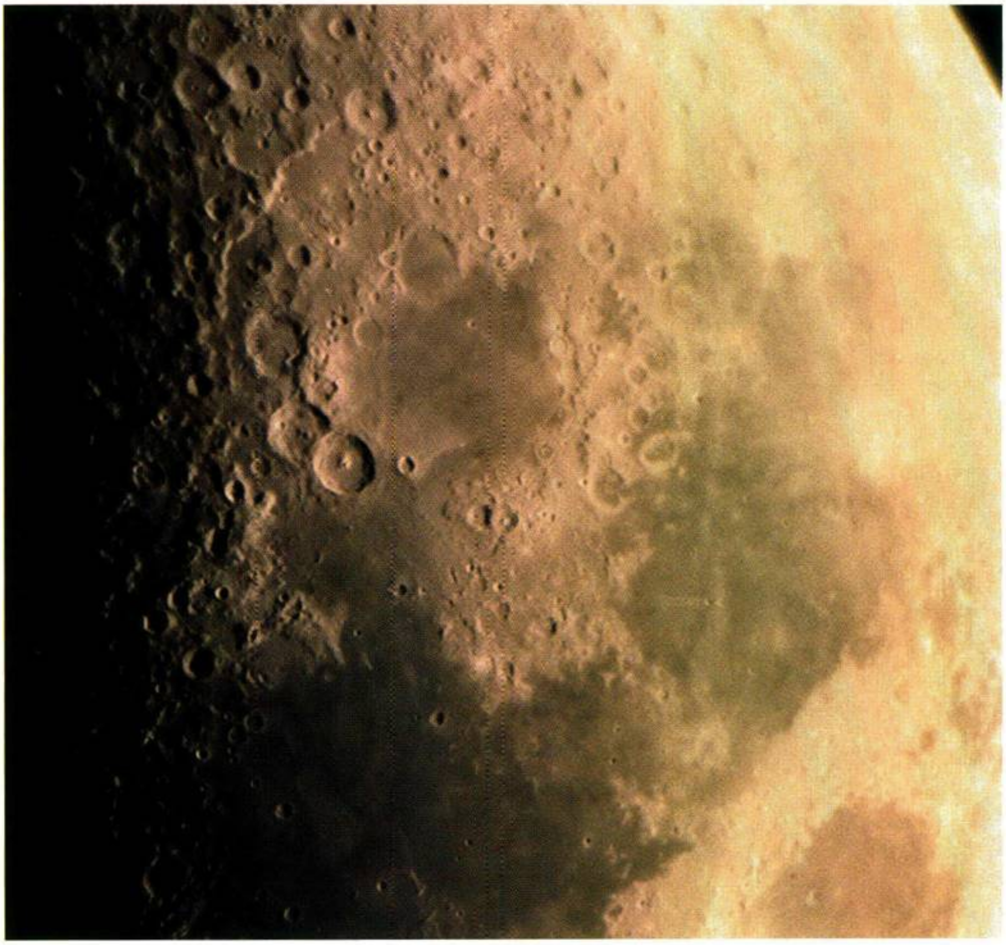
Eclipse Trekking

▶ No obstacle is too great for the dedicated amateur astronomer, as two *Astronomy* readers recently proved. On January 8, 2001, Oshin Zakarian put all worries of bad weather and unforeseen problems aside and caught a bus to Shiraz, a famous ancient city in Iran. His goal was to catch the first lunar eclipse of the millennium over Pasargade, which contains the ancient tomb of Cyrus the Great (founder of the Achemenian Empire), now a historical landmark.

During the 15-hour trip, a harsh snowstorm and heavy cloud cover began to narrow the chances of viewing this spectacular phenomenon. Sure enough, as Zakarian arrived at the tomb on the morning before the eclipse, snow had given way to dense fog and rain. Although the rain eventually subsided, by nightfall thick clouds still blocked the entire sky.

But, as many observing buffs are well aware, the weather can change in a blink of an eye. Miraculously, at about 9 P.M. local time, approximately 20 minutes before the eclipse was to begin, the clouds parted and the moon shone brightly over the tomb. "Certainly this was not by chance," says Zakarian. "It was just like a theater curtain opening before the beginning of the show."

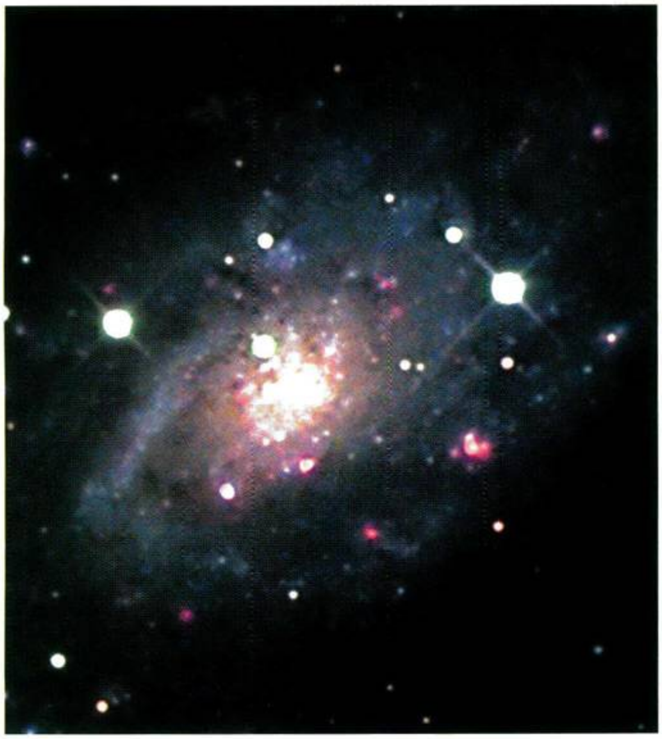
The eclipse proved to be an unforgettable show, with the ancient tomb, snow-covered mountains, and the sounds of wild animals setting the scene. Finally, at



The Central Face of the Moon

BOB VANDUSEN

(8-inch f/10 SCT, Fuji 200 ISO film, 1/30-second exposure taken July 7, 2000)



Spiral Galaxy NGC 2403 in Camelopardalis

ROBERT GENDLER

(12.5-inch Ritchey-Chrétien scope, ST8E CCD camera, composite of four exposures)

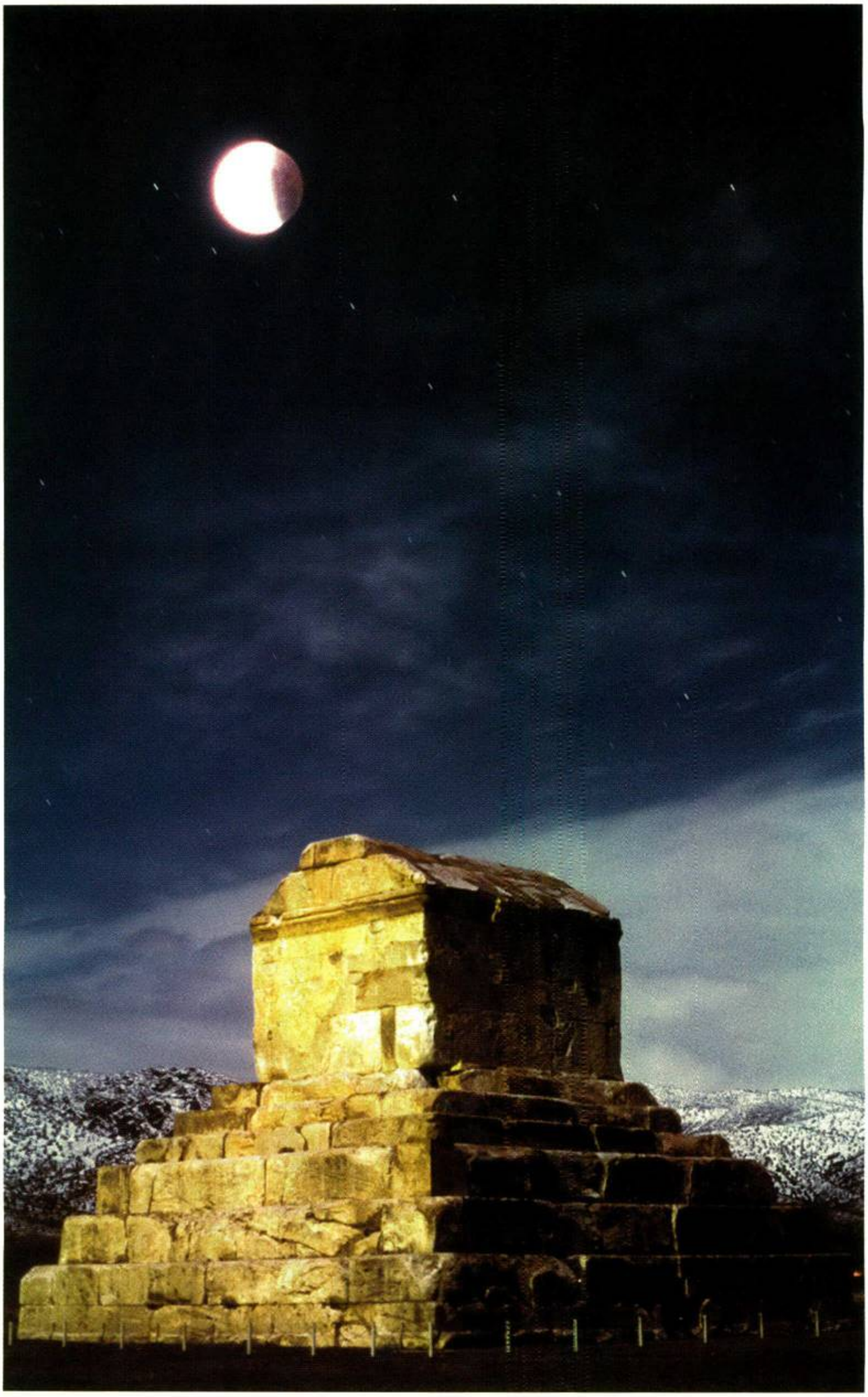
1:29 A.M., the eclipse ended. And to Zakarian's astonishment, clouds covered the moon once again. "This was a dramatic end to the first lunar eclipse of the century, one I will remember for the rest of my life."

About a month later, on the other side of the world, another hopeful observer proved that challenges can be overcome. Pennsylvania resident Vince Mollichella had dreamed of witnessing a shuttle launch for as long as he could remember. Although he had made several trips to Florida in hopes of seeing a launch from Kennedy Space Center, the timing never cooperated. "I live near Philadelphia, so it's very difficult to plan a trip around a shuttle lift-off," he says.

Upon checking NASA's schedules, he discovered that the closest one was the launch of STS-98, scheduled a month earlier in January.

But knowing how unreliable these schedules can be, Mollichella checked again the week STS-98 was to lift off. To his dismay, he discovered the launch had been moved to February 6, one day before he was to arrive in Florida. On a whim, he checked the schedule one last time before his trip, and was met with the news he had hoped for: the launch of STS-98 had been rescheduled for the evening of February 7. His plane was to land in Florida on noon of that day.

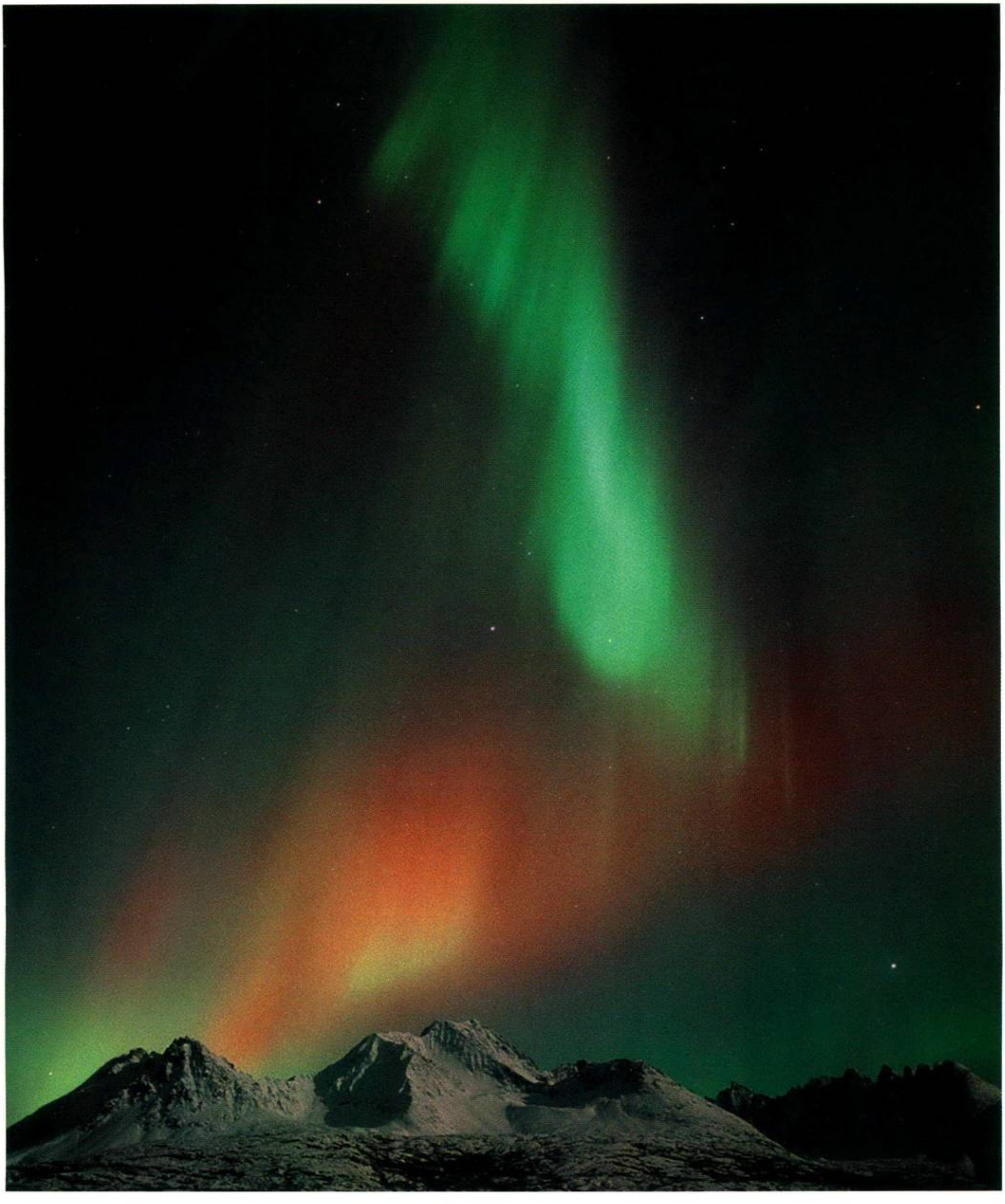
The day of the launch finally came, and although Mollichella still worried that the launch date would be moved again, he arrived in Florida to find that everything seemed to be perfectly on schedule. The launch was to take place at 6:11 P.M. local time. Arriving



Lunar Eclipse over Tomb of Cyrus the Great, Pasargade, Iran

OSHIN D. ZAKARIAN

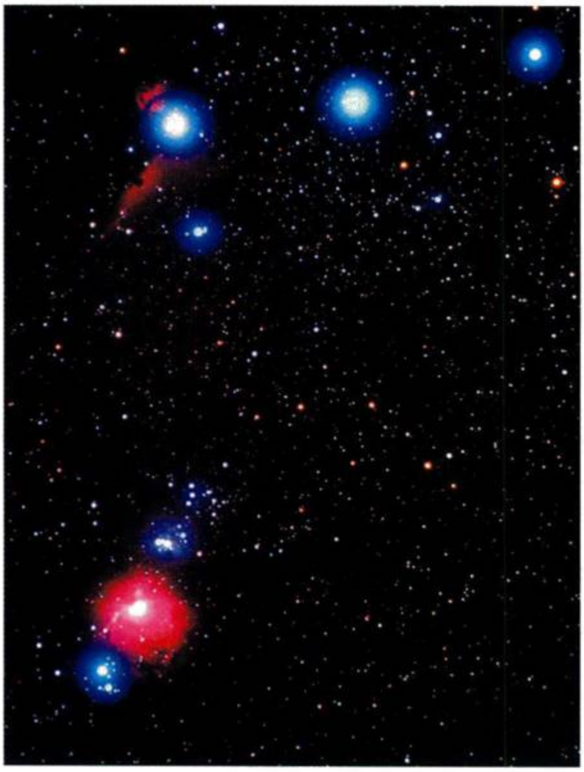
(50mm lens at f/4, Ektachrome 200 film, ⅛-second exposure taken January 9, 2001)



Aurora over the Sawtooth Range near Skagway, Alaska

MICHAEL KLENSCH

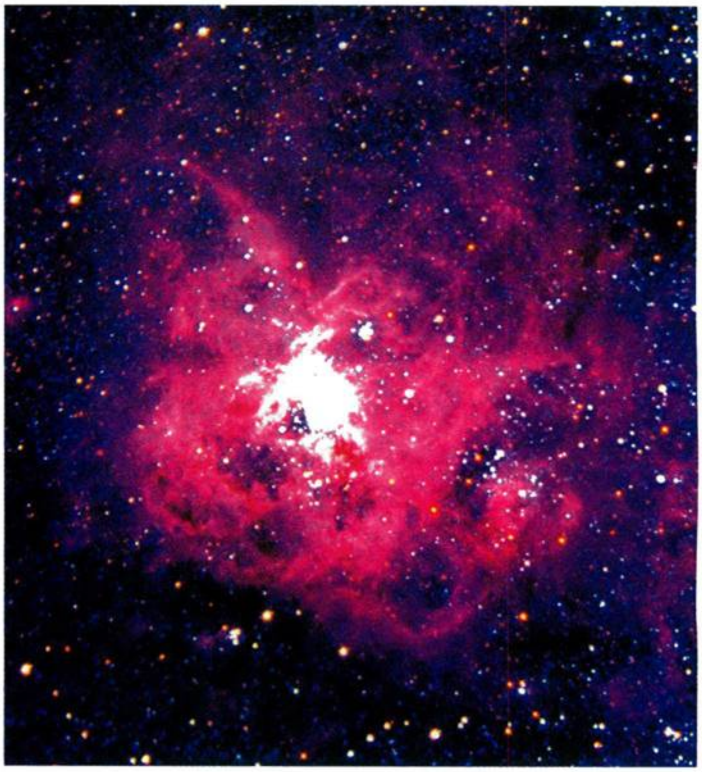
(24mm lens at f/2.8, Fuji Superia 200 film, 15-second exposure taken November 10, 2000)



Orion's Sword and Belt Sparkles

STEPHEN PITT

(300mm lens at f/2.8, Fuji HQ film, 15-minute exposure)



The Tarantula Nebula in the Large Magellanic Cloud

JAMES R. FOSTER

(11-inch SCT at f/6.3, Fuji HG 400 film, 85- and 65-minute exposures)

at the sight three hours early, he waited impatiently.

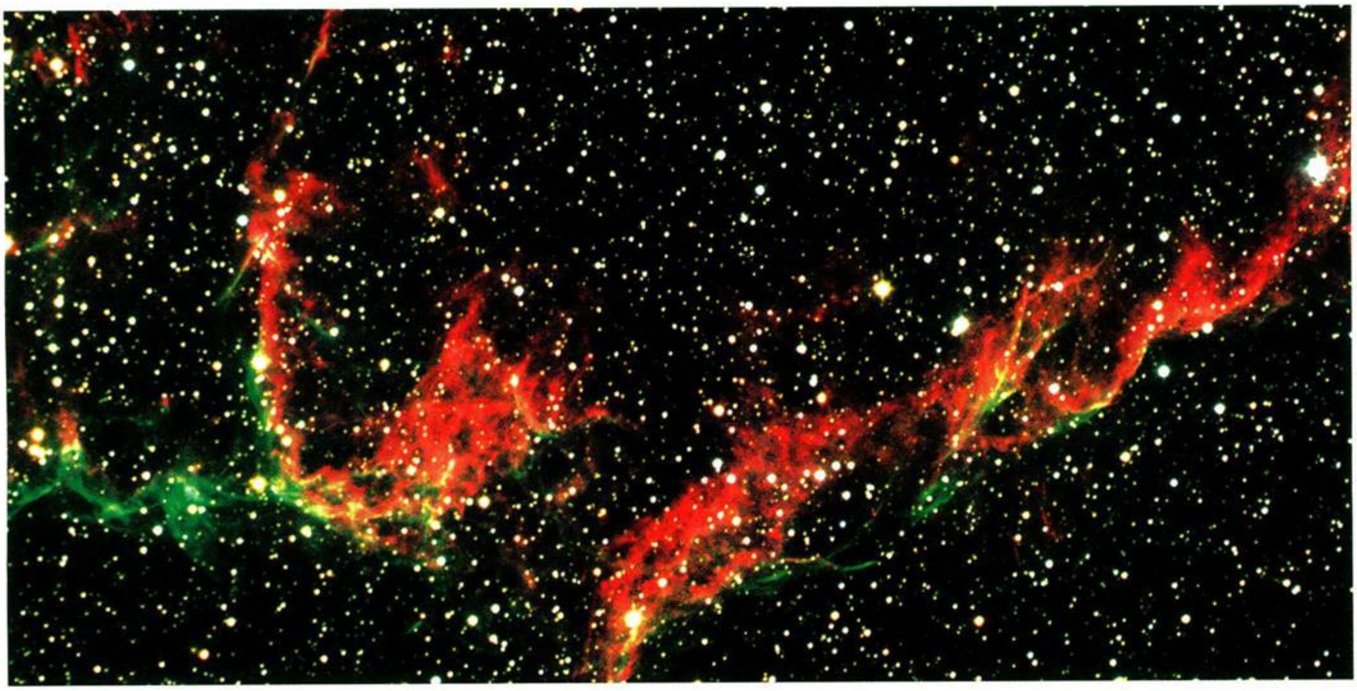
"Finally, at 6:13 P.M., I saw what looked like a match being lit on the right-hand launch pad," Mollichella remembers. "The shuttle took off into clear blue skies and headed right past the moon, creating a great sight. A boyhood dream came true." ■

Share Your Stories
Send your 500- to 800-word reports describing your observing experiences to:
Hot Shots, *Astronomy* magazine, P.O. Box 1612, Waukesha, WI 53187-1612
Or e-mail them to:
hotshots@astronomy.com

Fireflies Compete with Star Trails

FABRIZIO MELANDRI

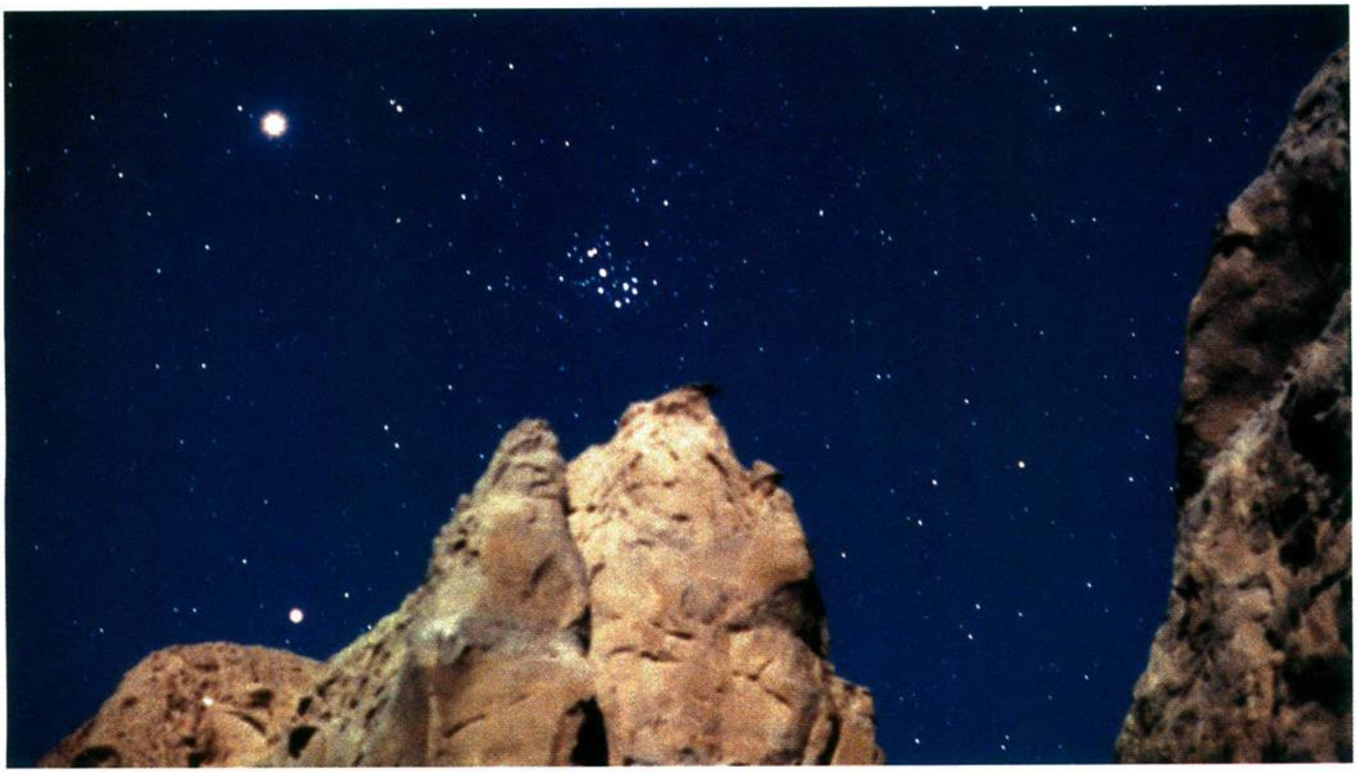
(50mm lens at f/1.8, Kodachrome 200 film, taken from Voltana, Italy)



Eastern Loops of the Veil Nebula

CLIFF WRIGHT

(18.2-inch reflector at f/2.8, ST8E CCD camera, composite of six exposures)

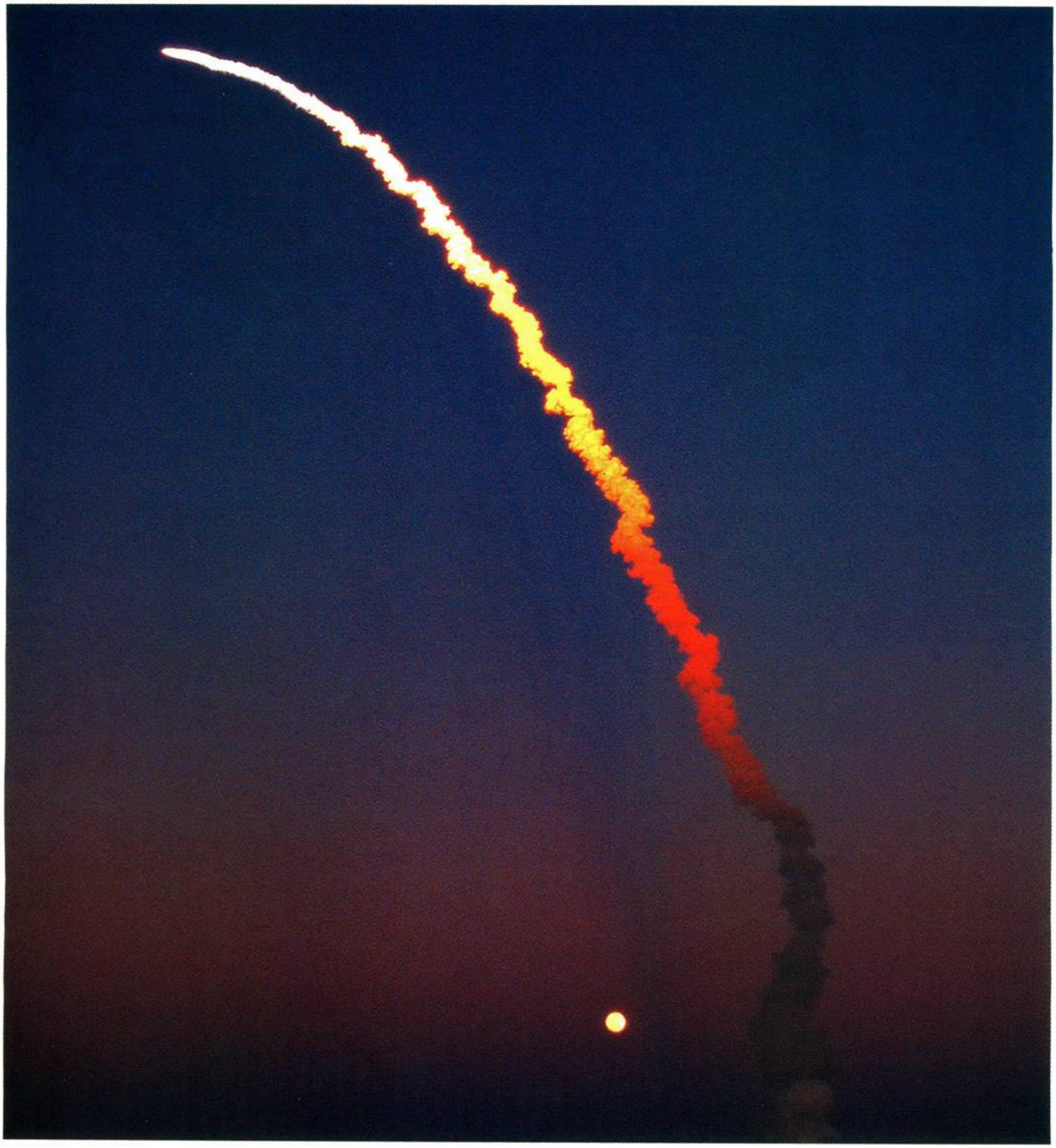


Jupiter, Saturn, and the Pleiades over Caprizio Badlands, Anza-Borrego Desert, California

JERRY SCHAD

(85mm lens at f/1.7, Kodak P1600 film at ISO 3200, 18-second exposure taken December 16, 2000)

This month's best astrophoto



Space Shuttle Atlantis Launches into the Florida Sky

WARREN T. PARKES

(400mm lens at f/5.6, Kodak EBX 100 film, 1/30-second exposure taken February 7, 2001)

Arizona photographer and amateur astronomer Parkes traveled to the Cape to witness the fury of a shuttle launch, capturing this pretty scene with the sun near the exhaust plume.

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* Patent pending.

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